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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR

ZIRCONIUM

PART II. DOMESTIC AND FOREIGN DEPOSITS

BY

E. P. YOUNGMAN

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ZIRCONIUM[1]

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By E. P. Youngman[2]

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2 - Rare metals and nonmetals division.

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FOREWORD

Zirconium, formerly distinctly a rare element, is rapidly becoming of rather extensive commercial importance. Economic features of the zirconium industry, together with general information regarding the metal and its compounds, are discussed in a separate paper,[3] to which this paper is a supplement.

In addition to giving a brief discussion of the four or five deposits that so far have proved to be commercial sources of the element, this circular summarizes available data (including some hitherto unpublished material from the files of the Bureau of Mines) upon other occurrences, including many of scientific interest only, of the two commercial minerals, zircon and baddeleyite, and also data upon some of the minor minerals, such as eudyalite and cyrtolite, which have attracted additional interest in recent years because they are frequently richer in hafnium than the more common zirconium minerals.

NORTH AMERICA

United States and Territories

Alaska

Zircon has been found in black sand from Cape Nome, Eagle River, and Yukon Territory, Alaska.[4]

Arkansas

Lee[5] is authority for the statement that eudyalite (variant eucolite) has been reported in the United States in Arkansas alone. In 1861 Shepard[6] found at Magnet Cove, Ark., imperfect rounded crystals of eudyalite, imbedded in feldspar and associated with aegirine, all three minerals belonging to the extensive elaeolitic rock of that region. At first he thought the newly discovered mineral to be corundum, as its color was a rich crimson, varying to peach-blossom red. However, after testing its hardness (somewhat under 6), and after observing that it quickly gelatinized in chlorhydric acid, he decided that it was eudyalite.

3/ Youngman, E. P., Zirconium, Part I: Inf. Cir. 6455, Bureau of Mines,

4/ Pratt, Joseph Hyde, Zircon, Monazite, and Other Minerals Used in the Production of Chemical Compounds Employed in the Manufacture of Lighting Apparatus: North Carolina Geol. and Econ. Survey, Bull. 25, 1916, p. 18.

5/ Lee, O. Ivan, Mineralogy of Hafnium: Chem. Rev., vol. 5, No. 19, Am. Chem. Soc., 1928, pp. 29-35.

6/ Shepard, Charles Upham, Mineralogical Notices: Am. Jour. Sci. and Arts, ser. 2, vol. 37, May, 1864, p. 407.

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In 1890 Williams[7] published an article upon the eudyalite and eucolite of Magnet Cove, confirming the conclusions of Shepard and others, and describing the crystals in detail.

The exact locality in which the minerals occur Williams described as follows:

> Both eudyalite and eucolite occur in two places in Magnet Cove: one, 100 meters northeast of the point where the Hot Springs turnpike crosses Cove Creek, and the other on "the branch" about 150 meters east of where it empties into Cove Creek. Indications of eudyalite have been observed in the elaeolite syenite of Saline County, Ark., on the property of Sol. Nethercutt, about 7 miles (11 kilometers) northeast of Benton (N. W. of S. E. of S ec. 16, 2S. 14W.). At this point the mineral was so badly weathered that an exact determination was impossible.
>
> Besides the aegyrite, elaeolite, and orthoclase of the rock in which the eudyalite occurs, there are found as accessory minerals beautiful little idiomorphic titanites and apatites. As decomposition products there appear ozarkite (thomsonite) and manganopectolite, which may be due in part at least to the weathering of eudyalite as well as of the other constituents of the rock.

Arizona

Pratt[8] reported zircon in Maricopa and Yavapai Counties. Day and Richards[9] reported the finding of zircon in the sands at Wickenbury, Maricopa County; at Arizona City, Skull Valley, and Prescott, Yavapai County; in the Santa Rita Mountains and at Greaterville, Pima County; and at Tucson, Pinal County.

California

Pratt[10] reports zircon in the following counties of California: Butte, Calaveras, Del Norte, Eldorado, Humboldt, Los Angeles, Nevada, Placer, Riverside, Sacramento, San Luis Obispo, San Mateo, Santa Barbara, Santa Cruz, Shasta, Siskiyou, Trinity, and Yuba. The counties of Plumas, San Barnardino, and Tuolumne are added by Day and Richards[11] in an article

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7/ Williams, J. Francis, Eudyalite and Eucolite, from Magnet Cove, Arkansas: Am. Jour. Sci., 3d ser., vol. 40, Nos. 235-240, July to December, 1890, pp. 457-462.

8/ Pratt, Joseph Hyde, Work cited, p. 18.

9/ Day, David T., and Richards, R. H., Useful Minerals in the Black Sands of the Pacific Slope: Min.Res. of the United States, 1905, U. S. Geol. Survey, 1906, pp. 1180-1181.

10/ Pratt, Joseph Hyde, Work cited, p. 18.

11/ Day, David T., and Richards, R. H., Work cited, pp. 1175-1258

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upon the black sands of the Pacific Coast. This article, which shows that zircon stands fifth in point of frequency (quartz being omitted in the estimate) in the sands of the States investigated, gives not only the counties in California (and other States) in which zircon occurs but the number of pounds of zircon to a ton of sand in each locality.[12]

Logan[13] says that zircon exists in small quantities as a primary constituent of the granodiorite that forms so large a part of the country rock east of the Sacramento Valley. In places where the sand is an accumulation from the erosion of the granodiorite, zircon is part of the heavy concentrates. No real work has been done so far to determine the practicability of recovering it.

Turner[14] discusses specimens of zircon crystals from heavy sands from gravel washings sent to him from a surface placer in Eagle Gulch, near Edmanton, about 4.5 kilometers southwest of Meadow Valley, Plumas County. Prof. S. L. Penfield, of the Sheffield Scientific School, who examined some of these crystals, reported as follows:

> The zircon crystals resemble ones that I have seen associated with gold from North Carolina. The forms are not unusual, 100, 110, 111, 311, and possibly 101. The hexagonal plates, referring to the crystals obtained by fusion with sodium carbonate (Na_2CO_3), resemble those I have met in testing for zirconia. I do not consider the reaction a very delicate one. The black grains may be chromite or some spinel mineral that would resist treatment with acids.

Colorado

Pratt[15] reported the existence of zircon in the following counties of Colorado: Chaffee, Costilla, Eagle, Huerfano, and Routt. Day and Richards reported zircon in the sands examined in these counties and in Gilpin, Jefferson, and Summit Counties as well. For details as to localities, see article by Day and Richards.[16] Lee reported cyrtolite in Colorado, though he stated that it is very sparing in occurrence.[17]

Free made an examination of pitchblende from Colorado because, as he said, it is the only important uranium mineral stated to contain zirconium, and because among uraninites of the United States of America it is

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12/ Day, David T., and Richards, R. H., Work cited, pp. 1182-1190.
13/ Logan, C. A., Sacramento Field Division; Placer County; Zirconium: Dist. Rept. Min. Eng., Rept. 23 of the State Mineralogist, vol. 23, No. 3, California State Min. Bur., July, 1927, p. 286.
14/ Turner, H. W., Notes on Rocks and Minerals from California: Am. Jour. Sci., 4th ser., vol. 5, No. 30, June, 1898, p. 426.
15/ Pratt, Joseph Hyde, Work cited, p. 18.
16/ Day, David T., and Richards, R. H., Work cited, pp. 1190-1194.
17/ Lee, O. Ivan, Work cited, pp. 24-25.

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unique in being analogous to the Joachimsthal pitchblende. His report is, in substance, as follows:18/

> The lead-uranium ratio was very small and indicates a maximum age of 2,000,000 years. This establishes the recent formation of the mineral in contradiction to the other United States of America uraninites examined by Hillebrand and Boltwood. The identity of the constituent thought by Hillebrand to be zirconium has been confirmed, and no thorium or rare earths could be detected in the mineral. Analysis of the mineral gave 78.9 per cent UrO_3, 5.25 per cent ZrO_2, with SiO_2, pyrites, and moisture as important constituents, and traces of lead, titanium, and vanadium. A comparison of the density of the zirconia separated from large quantities of the mineral with specimens of zirconia separated from a blue Siamese zircon, reputed to be rich in hafnium, and with a commercial zirconia preparation, showed that all these specimens were of similar low density and therefore of similar low-hafnium content. The spectra of the preparations were also similar and gave no evidence of any difference in hafnium content.

The zircon from the Pike's Peak district, Colo., has been described by Cross and Hillebrand.19/ In a prospect tunnel near the Pike's Peak toll road, almost directly west from Cheyenne Mountain, unusually beautiful transparent crystals were found in moderate abundance in a small quartz vein.

Connecticut

Cyrtolite occurs, although very sparingly, in Connecticut, the Branchville (Conn.) cyrtolite being mentioned by Lee20/ as one of the richest in hafnia in the United States.

Florida

The plant of Buckman & Pritchard (Inc.), at Mineral City, Fla., which had a recorded production of zircon from 1922 to 1928, ceased operation in 1929. The plant at Mineral City was first built for the recovery of ilmenite and was later adapted to the recovery of zircon and rutile also.

The composition of the concentrates of the Florida sands is as follows:21/

18/ Free, O., Zirconium in Colorado Pitchblende: Phil. Mag., vol. 1, May, 1926, pp. 950-960. (Sci. Abs., vol. 29, Nov. 25, 1926, P. 820.)

19/ Cross, Whitman, and Hillebrand, W.F., Communications from the U. S. Geological Survey, Rocky Mountain Division, II; Notes on Some Interesting Minerals Occurring near Pike's Peak, Colo.; Zircon: Am.Jour. Sci., 3d ser., vol. 24, No. 142, Oct., 1882, pp. 284-286.

20/ Lee, O. Ivan, Work cited, pp. 24-25.

21/ Martens, James H. C., Beach Deposits of Ilmenite, Zircon and Rutile in Florida: 19th Ann. Rept. Florida State Geol. Survey, 1926-27, 1928, p. 137.

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Minerals	Per cent
Ilmenite	55
Zircon	20
Rutile	6
Monazite	2
Greenspar	14
Quartz	3

With respect to the occurrence of zircon in the beach sands at Mineral City, Fla., Martens says:22/

> Zircon is almost universally present in quartz sand, but the size of the grains and the proportion of them are so small that it can rarely be seen without using a microscope or without concentrating the mineral in some way, or both. However, on some of the beaches where natural concentration of the heavy minerals is going on, light-colored streaks of zircon may be seen among the darker rutile and ilmenite. The zircon can then be distinguished from quartz by its brilliant luster and smooth crystal faces. The zircon separated from the sand at Mineral City is in grains usually about 0.1 millimeter in diameter, but varying considerably in size and shape. Each of the grains is a single crystal; many of them show the crystal faces to a high degree of perfection, while others appear worn or broken. There are a few prismatic crystals as much as four or five times as wide, but crystals only slightly elongated are far more abundant. Practically all of the zircon on the Atlantic coastal beach from Mineral City to St. Simons Island (Georgia) is of the colorless variety, rarely showing zonal structures. Pale-purple or lavender grains of zircon are present but are very rare.

The following description of the beach deposit in general is also by Martens:23/

> From the mouth of the St. Johns River to St. Augustine Inlet, a distance of 35 miles, the ocean beach . . . is nearly straight and is rather uniform in its topographic features . . . The width of the beach for most of this distance is about 500 feet at low tide. At the back of the beach is a line of dunes usually a few hundred feet wide and varying in height up to 30 feet or a little more. A large part of the way along the beach there is a distinct wave-cut cliff or notch in the dune front, which has been produced during storms, since it is not reached at high tide in calm weather. For many miles inland none of the land is as high as the highest dunes, and from Mineral City southward to St. Augustine Inlet, there are marshes immediately in back of the dunes.

22/ Martens, James H. C., Work cited, p. 133.
23/ Martens, James H. C., Work cited, pp. 127-129.

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The heavy concentrate or ore always occurs in beds, which may best be described as "strips" since the bodies are much wider than they are thick and much longer than they are wide, the direction of greatest extent being parallel to the shore. The principal beds occur on the back part of the beach at the foot of the dunes and extending out a short distance in front of them. . . . The ore is in the form of a fine sand, even finer than the ordinary beach sand, and is easily recognized by its dark color and heavy weight. A cut through the back part of the beach will usually reveal a succession of thin light and dark beds, the dark ones varying in thickness from a small fraction of an inch up to about 6 inches, while the light ones are generally thicker. . . . There is frequently a fairly thick layer of black sand almost immediately below the surface, while deeper down there is a succession of thinner layers of light and dark.

During the early period of working, the richest streak of black at the foot of the dunes contained 60 per cent of "mineral" (heavy minerals recovered in the wet mill) for a thickness of 2 to 2½ feet and a width of 25 to 35 feet, but the average of the sand as worked has recently been around 20 per cent "mineral" and the dimensions as worked somewhat smaller. Samples can be obtained that are practically free from quartz and therefore may be said to contain 100 per cent "mineral," but such material is in too thin layers to select it in mining; so a certain amount of the quartz sand has to be mined also. All of the dunes and beach sand contain some of the ilmenite and associated minerals; so that there is not always a sharp distinction between material that is workable and that which is not. Besides the beds on the back part of the beach, some of the adjoining part of the dunes selected as appearing richest in dark minerals has also been worked.

The workings have extended 3 miles north of the mill at Mineral City and 8 miles south. To the north the deposits continue somewhat farther, but the beach is developed as a pleasure resort to such an extent as to prevent mining operations. Farther to the south the heavy concentrate probably is of workable grade and depth for several miles and is likely to be mined when a road is built so as to make it more readily accessible.

Both the heavy concentrates and the associated beach and dune sand are entirely loose and unconsolidated and of very fine texture. The sand of the lake beaches is generally coarser than that of the ocean beach. The same heavy minerals are present in the ordinary beach and dune sand as in the heavy concentrate, but in much smaller amount. There are all gradations from the dark heavy concentrates with only a few per cent of quartz to sand that is practically all quartz with only scattered grains of the heavy minerals. . . .

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Microscopic examination is the only practicable method of determining the mineral composition since there is too complicated a mixture for chemical analysis to be of much help, and anything approaching complete separation of the minerals by mechanical means is excessively difficult.

Other occurrences of zircon in Florida, which are of no commercial value as yet, as reported by Martens[24] are as follows:

1. Amelia Island.--Specimens from heavy concentrates from the beach and dune sands of Amelia Island, at the extreme northeastern corner of the State, show by analysis 11.3 and 24.1 per cent of zircon.

2. Eau Gallie.--One and one-half miles north of the main part of Eau Gallie, on the west side of Indian River, the beach has heavy mineral concentrates, as do also the beaches at several other places on Indian River. The percentages of zircon in specimens tested are 14.7 and 15.

3. Gulf Beach at Venice.--For a distance of 2 miles or more south of Casey's Pass, on the gulf beach near Venice, the heavy minerals are abundant. The zircon, being the heaviest of the minerals present in any large amount, is left highest on the beach by the waves. Some of the rich zircon sands (scraped from a layer a fraction of an inch in thickness) yielded 68.6 and 69.4 per cent of zircon. The more common deposits of concentrates at Venice yielded 6.6 and 11.2 per cent of zircon.

4. Cape San Blas.--Heavy mineral concentrates extend for some miles along the upper part of the gulf beach on the peninsula between Cape San Blas and Point St. Joseph. The deposit is not wide and thick enough to be commercially important under present conditions. Analyses show 5 and 15.7 per cent of zircon in the sands.

5. Crooked Island.--On the mainland side of Crooked Island (Bay County), along St. Andrews Sound, are deposits of heavy concentrates from about low tide to above high tide; and on the outer beach of the island, almost opposite the end of the road from Auburn to St. Andrews Sound, are thin layers of heavy concentrates, which alternate with quartz sand. Examination of the island did not disclose deposits large enough to be workable; however, but a small part of the island was included in the investigation. Specimens analyzed showed 17.9 and 20.5 per cent of zircon.

6. Inlet Beach.--In Walton and Bay Counties, on the gulf beach, for a distance of 2 miles to the east and 5 miles to the west of Phillips Inlet, the darker minerals are found in the sands, although

24/ Martens, James H. C., Work cited, pp. 141-147.

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the light sands predominate. On the back part of the beach layers of heavy dark concentrates alternate with white quartz sand. The composition of the sand is similar to that from Crooked Island and Cape San Blas. However, there is less zircon here than in the other two localities.

7. Santa Rosa Island.--Heavy sands, the composition of which is similar to that of concentrates on Crooked Island, occur in thin narrow strips along the shore on the north side of Santa Rosa Island, opposite Camp Walton.

8. Lake Beaches.--Deposits of heavy mineral concentrates, not extensive enough to justify exploitation, exist on many lake beaches, such as Barnes' Beach, on the north side of Lake Weir, Marion County (2.1 and 3.5 per cent of zircon); east side of Lake Geneva, Clay County (40.2 and 57.6 per cent of zircon); and Kingsley Lake Beach, at Strickland's resort, Clay County (0.3 and 0.4 per cent of zircon).

Georgia

According to Teas,[25] on a number of islands along the Atlantic coast of Georgia (as well as of Florida) black sands have been found in which the content of rare minerals is believed to be sufficiently large to warrant their consideration as commercial deposits.

At the southern end of St. Simon Island (which lies northeast of Brunswick, and which is reached by boat from that city), near the wharf and in front of the lighthouse, occur the heaviest concentrates, extending almost half a mile. The dark minerals are on the upper part of the beach sands, between high and low tide marks. Back from the sea the black sand is covered by wind-shifted sands to a depth of 1 to 10 feet. An analysis of the sand from St. Simon showed 0.12 per cent of zirconium oxide.

On Sapelo Island, which is reached by boat from Darien, the black sand is most plentiful a short distance north of the lighthouse, which is at the south end of the island. It is found, however, over most of the island, especially along the beaches--the dunes not containing much of the darker sands. An analysis of a specimen from the richest deposit, north of the lighthouse, which showed 5 to 6 per cent of the dark minerals, indicated the presence of quartz, ilmenite, magnetite, monazite, and zircon, the relative abundance thereof being indicated by the order in which they are given. The percentages of zirconium oxide in two tested samples were 0.08 and 0.1.

In Charlton County, 3 miles west of St. George, sand similar in mineral content to that of the coastal islands was reported to be associated with deposits of sap brown along the Georgia and Florida Railway.

25/ Teas, L. P., Sand and Gravel Deposits of Georgia: Geol. Survey of Georgia Bull. 37, 1921, pp. 376-377.

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Idaho

The report of Day and Richards upon the minerals in the black sands of the Pacific slope[26] lists the following counties of Idaho in which zircon occurs: Ada, Bannock, Bingham, Blaine, Boise, Canyon, Custer, Elmore, Fremont, Idaho, Lemhi, Lincoln, Nez Perce, Owyhee, Shoshone, and Washington. The individual sand deposits are too numerous to mention here.

Minute crystals of zircon are prevalent in the metamorphosed rocks of the Pend Oreille mining district, an area 15 by 20 miles; and in the near-by Coeur d'Alene district, also, zircon is very abundant in the sedimentary rocks that are directly correlated with the pre-Cambrian formations of the Pend Oreille district, as shown by Joseph L. Gillson, from whose report[27] upon zircon as a contact metamorphic mineral in the Pend Oreille district the following excerpts are taken:

> The sedimentary rocks of the district belong to the Belt series (Algonkian) and the Cambrian. Except for one calcareous member, the Belt rocks consist of a great thickness of thoroughly indurated sandstones and shales, and the Cambrian rocks consist of quartzite, shale, and limestone. A very large batholith extends from the west side of the district westward for many miles, and three stocks, each from two to three miles across, outcrop within the area. These igneous bodies are so large and are so near to each other even at the surface that a widespread effect of igneous metamorphism would be expected in the invaded sedimentary rocks. In fact no locality in the quadrangle was found where the sedimentary rocks did not show at least some microscopic evidence of igneous metamorphism.
>
> Detrital zircon is commonly present in the noncalcareous rocks; but little or none is present in the calcareous rocks. . . .
>
> The evidence from the calcareous rocks, more striking than that in the noncalcareous rocks, leaves no room for doubt that zircon is a contact-metamorphic mineral. The sequence of the mineralization under the contact metamorphic conditions in the sedimentary rocks of the Pend Oreille district indicates that the zircon belongs to a second or pneumatolytic stage in the metamorphism and formed contemporaneously with tourmaline, biotite, andalusite, cordierite, vesuvanite, garnet, diopside, apatite, etc. Unlike these minerals the zircon is of unrestricted occurrence and is found in both calcareous and noncalcareous rocks.

26/ Day, David T., and Richards, R. H., Work cited, pp. 1194-1200.
27/ Gillson, Joseph L., Zircon, a Contact Metamorphic Mineral in the Pend Oreille District, Idaho: Am. Mineral., Jour. Mineral. Soc. Am., vol. 10, No. 8, Aug., 1925, pp. 187-194.

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Indiana

Zircon was found (in the proportion of 66 pounds to a ton of sand) in sands from Michigan City, Laporte County, Ind.[28]

Maine

Zircon is known to occur in pegmatite at Auburn, Me. In the town of Norway, near Cobble Hill, perfect crystals of zircon, with chrysoberyl and zinc spinel, occur in the pegmatite. Zircon crystals one-sixteenth to one-eighth inch long lie upon slickensided surfaces, of which Bastin says, "They were probably formed during the shearing process." Zircons, associated mostly with triphyllite and rarely exceeding one-eighth inch in diameter, have been found in the pegmatite of Mount Mica, Paris, Me.[29]

Maryland

Zircon was found in sands examined in Maryland: from a trace at Glyndon to 2 pounds per ton of sand at Harrisonville (Baltimore County); and 19 pounds per ton at Ocean City, in the beach sand (Worcester County).[30]

Massachusetts

The cyrtolite at Rockport, Mass., although very rare, is unusually rich in hafnia, containing as much as 17 per cent thereof.[31]

Mississippi

A trace of zircon was found in sands examined at Magnolia, Pike County, Miss.[32]

Montana

Zircon has been reported as occurring at Wisdom, Beaverhead County; Miles City, Custer County; and in Powell County, Mont.[33]

Austin F. Rogers, while examining specimens of corundum from an unknown locality in Montana (obtained from Ward's Natural Science Establishment), discovered a black submetallic mineral, which he proved to be baddeleyite. Baddeleyite has been identified by Rogers in specimens from the property of the Bozeman Corundum Co., 14 miles southwest of Bozeman. The baddeleyite of Montana is an accessory constituent of a gneissoid

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28/ Day, David T., and Richards, R. H., Work cited, p. 1200.
29/ Mining and Engineering World, ---: Vol. 37, 1912, p. 1018.
30/ Day, David T., and Richards, R. H., p. 1202.
31/ Lee, O. Ivan, Work cited, pp. 24-25
32/ Day, David T., and Richards, R. H., Work cited, p. 1202.
33/ Day, David T., and Richards, R. H., Work cited, p. 1202.

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corundum-syenite containing microcline-microperthite, biotite, and corundum, with subordinate amounts of muscovite, sillimanite, and zircon.[34]

New Hampshire

According to Pirsson and Washington,[35] microscopic study of the foyaite type of nephelite syenite reveals zircon in thin sections at Red Hill, Moultonboro, N. H. The zircon, not very common, is in rough crystals or grains that have a general though sparse distribution. The crystals vary from 0.2 to 0.4 millimeter in diameter. The zircon is included with the accessory minerals in the umptekite variety of alkalic syenite.

The first occurrence of wöhlerite in an American locality (a well-known mineral characteristic of the nephelite-syenite pegmatite dikes of South Norway) was reported at Red Hill, where it is found everywhere distributed through the rock mass.

New Jersey

A report on the zircon of New Jersey by the United States Geological Survey[36] is quoted at length.

> Several localities in northern New Jersey, especially in Sussex County, have been reported to contain zircon-bearing ores and rocks, and an investigation of the deposits was undertaken to test their availability as a source of zircon. It has been concluded that if the demand for zircon should become imperative and if the mineral must be had at any cost, then several hundred tons could be obtained from northern New Jersey, but the locality does not offer any inducement as a commercial field. . . . The most promising pegmatite is that of the old Woods mine, about half a mile southeast of Stockholm, N. J. At least four shafts, now filled in, were made in a pegmatite dike about 10 feet wide and exposed for more than 100 feet. The pegmatite rock is composed of quartz, feldspar, magnetite, and zircon. There is too little magnetite in the rock to be worked as an iron ore. The shafts are said to have been dug long ago--maybe over 100 years. No ore is known ever to have been shipped away. The rock is richer in zircon than any other rock seen in this region. Some selected parts of the dike may carry as much as 5 per cent of zircon, but an average sample of 20 specimens of selected zirconiferous rock yielded only 1.53 per cent of zircon. The rock in the shaft at one end is much richer in zircon than the rock at the other end of the line of shafts. An average sample of 10 specimens, collected across the exposed dike at 1-foot intervals, con-

34/ Rogers, Austin F., Baddeleyite from Montana: Am. Jour. Sci., 4th ser., vol. 33, No. 193, Jan., 1912, pp. 54-56

35/ Pirsson, L. V., and Washington, H. S., Contributions to the Geology of New Hampshire, No. 3; On Red Hill, Moultonboro: Am. Jour. Sci., 4th ser., vol. 23, No. 136, April, 1907, pp. 261, 266, 267, and 270.

36/ Schaller, Waldemar, T., Thorium, Zirconium, and Rare-Earth Minerals: Min. Res. of the United States, 1919, pt. 2, U. S. Geol. Survey, 1922, pp. 21-22.

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tained 0.92 per cent of zircon. The pegmatite rock is hard and unaltered and would have to be crushed before any zircon could be obtained. The total quantity of zircon obtainable from this locality would not amount to more than a few hundred tons, and the expense would prohibit commercial exploitation.

Nevada

Traces of zircon were found in the sands of Dixie Creek and of Mascot, Elko County, and of Berlin, Nye County. Zircon was found at Carson City, Ormsby County, also.[37]

New Mexico

Day and Richards[38] reported the occurrence of zircon in the sands at Pinos Altos, Grant County; at Brice, Otero County; at Bernardillo, Sandoval County; and at Los Cerrillos and from Tuer to Arroyo, Santa Fe County.

New York

Morris says[39] that zircon occurs in New York, at Lyon Mountain, Clinton County; at a few places near Crown Point and abundantly in pegmatites at Old Red Mines, Mineville, Essex County; and at numerous places in Orange County, on the south, and St. Lawrence, on the north. Day and Richards[40] report small amounts of zircon found in the sands examined at Lowville and Rochester, Lewis County.

A deposit of cyrtolite, radioactive, in Westchester County, which Lee says has been twice authenticated as high in hafnia,[41] has been fully described in a circular upon hafnium, soon to be published by the Bureau of Mines.

North Carolina

North Carolina (the only State with the exception of Florida that has had a recorded production of zirconium ore in the United States) was the first producer of the ore. The silicate zircon was discovered in Henderson County in 1869. Production continued intermittently from 1869 until 1911. W. E. Hidden, according to Lee,[42] mined as much as 26 tons as early as 1883. The first shipment recorded, however, was in 1883,

37/ Day, David T., and Richards, R. H., Work cited, p. 1204.
38/ Day, David T., and Richards, R. H., Work cited, p. 1204.
39/ Morris, H. C., Zirconium: Political and Commercial Control of the Mineral Resources of the World, No. 7, Bureau of Mines, Nov. 15, 1918, pp. 9-13.
40/ Day, David T., and Richards, R. H., Work cited, p. 1204.
41/ Lee, O. Ivan, Work cited, pp. 24-25.
42/ Lee, O. Ivan, Work cited, pp. 24-25.

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when the ore was marketed to be used in the manufacture of mantles for incandescent lights. As thoria soon took the place of zirconia for this purpose, shipments of zircon ceased for a few years, beginning again in 1902, upon the introduction of the Nernst lamp. Although the North Carolina Geological Survey in 1916 reported[43] that shipments begun in 1903 had continued until 1916, no one year having a very large production, no output figures were reported to the United States Geological Survey.

The following description of the Henderson County deposit is by Schaller.[44]

> * * * Near Tuxedo (formerly called Zirconia) a pegmatite dike, about 100 feet wide and striking N. 50° E., cuts through the pre-Cambrian gneisses of the region and has been traced for a mile and a half. The upper part of the pegmatite is kaolinized and disintegrated to a depth of 40 feet or more. Zircon crystals are present in abundance in certain parts of the pegmatite but are not uniformly distributed throughout the dike. They are gray in color and show both the prism and pyramid about equally developed. They average in size from about an eighth to a quarter of an inch. They can be readily washed from the decomposed pegmatite or from the unaltered crushed rock.
>
> Two places have been worked on this pegmatite dike--the Freeman mine, near the southwest end of the dike, and the Jones mine, near the northeast end. * * *

Genth[45] described other occurrences of zircon in North Carolina as follows:

> Abundant with the gold sands of Burke, McDowell, Polk, Rutherford, Caldwell, Mecklenburg, Nash, Warren, and other counties, in very minute yellowish-brown and brownish-white, sometimes amethystine and pink crystals with many planes. . . . Found also by Dr. Hunter at Wall's farm, Gaston County. It is rarely found at Ray's mine, Hurricane Mountain, Yancey County, and the Flat Rock mine, Mitchell County. It has been observed in dark red-brown crystals in the magnetite beds of the Unaka Mountains; an irregular large crystal of about 2 inches in length and a pale brownish-gray color has been found by J. A. D. Stephenson near Statesville, Iredell County; and by the same, small crystals embedded in allanite, near Bethany church.
>
> Peculiar dark brown crystals from 1-3 millimeters in size are found at Low's and Tibbet's mine, in Macon County, which may be zircon. They need fuller investigation. Hidden reports, from the

43/ Pratt, Joseph Hyde, Work cited, p. 16.
44/ Schaller, Waldemar T., Work cited, p. 19.
45/ Genth, Frederick Augustus, The Minerals of North Carolina; U. S. Geol. Survey Bull. 74, U. S. Geol. Survey, 1891, p. 49.

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gold sands of Brindletown, good crystals of the variety malacone. The latter are jet black, with occasionally a grayish crust, and are larger than, and of different form from, the zircons directly associated with them. Specific gravity 4.087. The same authority reports the variety cyrtolite from several places, namely:

> Masses and distinct crystals having curved faces and gray-brown color have been met with at the Wiseman mica mine in Mitchell County, associated with autunite, fergusonite, and samarskite. Also at Mill's mine, near Brindletown, and at the xenotime and polycrase locality on the Davis land, near Green River, in Henderson County.

With the monazite at Mars Hill, Madison County, zircon crystals of considerable size are sometimes found. One such crystal, specific gravity 4.507, was analyzed by me as follows:

Loss on ignition	1.20
Silica	31.83
Zirconia	63.42
Ferric oxide	3.23
	99.68

Oklahoma

Mineral Resources of the United States for 1907[46] announced that a new deposit of zircon had been reported by Frank Rush, a forest supervisor of the Wichita National Forest. This deposit (which was later prospected by Hackney & Sons, La Harpe, Kans.) has been described as follows:[47]

> A pegmatite dike with many scattered zircon crystals occurs near the south edge of the Wichita National Forest, Wichita Mountains, about 7 miles northwest of Cash, Okla. The zircon crystals reach a maximum size of nearly an inch, though most of them are much smaller. They are simple pyramids with the prism faces nearly absent. Most of the crystals are deep reddish-brown, but a few are yellowish to nearly colorless.
>
> An investigation of the deposit seemed to indicate that only a very small quantity of zircon could be obtained, as the zircon-rich portion of the pegmatite was of slight extent.

46/ Sterrett, Douglas B., Monazite and Zircon: Min. Res. of the United States, 1907, pt. 2, U. S. Geol. Survey, 1908, pp. 792-793.

47/ Schaller, Waldemar T., Work cited, pp. 22-23

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Day and Richards[48] reported traces of zircon in the sands at Putnam, Dewey County, Okla.

Oregon

Zircon occurs in the following counties of Oregon, according to a report of Pratt:[49] Baker, Clatson, Coos, Lincoln, Curry, Douglas, Grant, Jackson, Josephine, Lincoln, Linn, Malheur, Multhomah, Polk, Umatilla, Wasco, and Washington. For the definite localities (far too numerous to mention here) in the counties just listed and in other counties, the reader is referred to the article by Day and Richards,[50] which has been quoted frequently in this paper.

Pacific Slope

That zircon stands fifth in the order of frequency (among 37 minerals in addition to quartz) in the black sands of the Pacific slope is claimed in a report[51] of the United States Geological Survey, which has been frequently referred to in these pages. A table covering 42 pages gives detailed information, by counties and smaller political divisions, concerning the occurrence of zircon (as well as of a dozen other minerals) on the Pacific slope. Magnetite, gold, ilmenite, garnet, hematite, chromite, platinum, iridosmium, mercury, amalgam, olivine, and iron silicates, pyrite, monazite, copper, cinnabar, cassiterite, and corundum are the other minerals most frequently found in the sands.

The action of a Wetherill separator on the zircon crystals is given on p. 1234, of Day and Richards' report.

Pennsylvania

Zircon is found in the following localities in Pennsylvania:

Berks County: Bernharts, Pricetown, and Trexler mica mine (Alsace).
Bucks County: Finney's quarry, Neshaminy Falls, Siles, and Vanarttsdalen's quarry.
Chester County: Chester Springs, Copesville, Pughtown, Springton, Octoraro Creek, West Chester (Bath Springs), and Willowdale.
Delaware County: Avondale (cyrtolite), Blue Hill, Boothwyn (cyrtolite), Brandywine Summit, Painter's farm on Dismal Run, and Morgan Station (cyrtolite).
Lehigh County: Macungie.
Montgomery County: Lafayette, Willow Grove.
Northhampton County: Chestnut Hill (gray or pinkish crystals 5 centimeters long).

48/ Day, David T., and Richards, R. H., Work cited, p. 1204.
49/ Pratt, Joseph Hyde, Work cited, p. 18.
50/ Day, David T., and Richards, R. H., Work cited, pp. 1206-1215.
51/ Day, David T., and Richards, R. H., Work cited, pp. 1175-1258.

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Philadelphia: Broad Street and Olney Avenue (cyrtolite), Bridesburg (colorless crystals in Delaware River sands), Comley's quarry (Mount Airy, cyrtolite), Fairmount Park, and in the Schuylkill River sands and gravels.

The following analysis is of zircon from Pricetown, Burks County, found as chocolate-brown crystals in magnetite:

	Per cent
SiO_2	34.07
ZrO_2	63.50
Fe_2O_3	2.02
H_2O	.50
	100.09

The specific gravity of the specimen of which the analysis is given is 4.595.[52]

South Carolina

Zircon occurs in South Carolina associated with magnetite sand or ore. Venable mentions an occurrence at Anderson, S. C., as being among the three localities in the United States where the mineral occurs in quantities sufficient for being mined.[53]

South Dakota

Day and Richards[54] reported zircon in the sands at Tinton and in the Hurricane district, Lawrence County; at Sheridan, Pennington County; and in the Big Horn Mountains.

Tennessee

Zircon occurs in Tennessee, associated with magnetite ore or with sand.[55]

Texas

Lee[56] lists Texas among the States found to be the richest in hafnium minerals, the altered zircon, cyrtolite, being found in abundance in Llano County. As early as 1889, Hidden and Mackintosh[57] described the cyrtolite of Texas as follows:

52/ Gordon, Samuel G., The Mineralogy of Pennsylvania; Descriptive Mineralogy of Pennsylvania: Special Pub. 1, Acad. Nat. Sci. of Philadelphia, 1922, p. 90.

53/ Venable, Francis P., Zirconium and Its Compounds: Am. Chem. Soc. Monograph Ser., Chemical Catalog Co. (Inc.), 1922, p. 18.

54/ Day, David T., and Richards, R. H., Work cited, pp. 1215-1216.

55/ Venable, Francis P., Work cited, p. 18.

56/ Lee, O. Ivan, Work cited, pp. 24-25.

57/ Hidden, W. E., and Mackintosh, J. B., A Description of Several Yttria and Thoria Minerals from Llano County, Texas: Am. Jour. Sci., 3d ser., vol. 38, Nos. 223-228, 1889, pp. 485-486.

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Cyrtolite has been found abundantly in both massive form and in good crystallizations. One hundred kilos have thus far been collected while mining the yttria minerals already herein described. This mineral here occurs in thick plates attached to the biotite and also constitution veins in the coarse pegmatite. It is often the matrix of the thoro-gummite and fergusonite. Specific gravity is 3.652. It occurs in tetragonal forms with all the planes rounded, and polysynthetic groupings of crystals are very common. Its color ranges from dull gray, through various shades of brown, to deep brown and almost black. Hardness about 5. . . .

Hidden,[58] a few years later, said:

Many hundred pounds of cyrtolite were found and in great variety of form and color. All kinds of it gave good radiographs after 24-hour exposures. Plates of it as large as one's hand, covered on one side with curved crystals, were not rare. It sometimes encrusted large quartz crystals to the depth of 1 inch, having radiate structure, and thus afforded a new feature for this mineral and one very uncharacteristic of zircon. . . .

Utah

Zircon was found in the sands examined at Hite, Garfield County, Utah; at Sand Springs, Iron County; at Morgan, Morgan County; at the junotion of the Combwash and San Juan Rivers, San Juan County; in Green River, Gensen district, and near Gensen, Uinta County.[59]

Virginia

Zircon has been discovered in both sedimentary and igneous rocks in Virginia, occurring in sandstone near Ashland and in pegmatites near Gouldin, Hanover County, and near Amelia Courthouse, Amelia County. The zirconiferous sandstone and the zircon-bearing pegmatites of Hanover County are less than a mile apart, the former being a "part of the western edge of the Coastal Plain, near and along the overlap of the sediments upon the older crystalline rocks of the Piedmont Plateau."[60] Under the heading "Genesis," the relation between the two different types of deposits in Hanover County is shown by Watson and Hess, as follows:[61]

The zircon and ilmenite concentration evidently represents an old beach segregation along but within the western margin of the

58/ Hidden, William E., Some Results of Late Mineral Research in Llano County, Texas: Am. Jour. Sci., ser. 4, vol. 19, No. 114, June, 1905, pp. 432-433.
59/ Day, David T., and Richards, R. H., Work cited, p. 1216.
60/ Watson, Thomas L., and Hess, Frank L., Zirconiferous Sandstone Near Ashland, Virginia: U. S. Geol. Survey Bull. 530-P, 1912, p. 3.
61/ Watson, Thomas L., and Hess, Frank L., Work cited, pp. 7-8.

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Miocene sediments of the Coastal Plain, of Calvert age, and is similar to the black-sand beaches of New Jersey, California, Oregon, and numerous other coasts and to the gold-bearing garnet (so-called "ruby") sands of the beaches at Nome, Alaska.

The zircon and other heavy minerals resistant to atmospheric agencies were derived by weathering processes from the crystalline rocks, chiefly granites and gneisses, of the Piedmont Plateau, which extend westward from the Coastal Plain contact . These formed the country rock of the shore, and the zircon and associated minerals derived from them by weathering were accumulated by waters near the mouth of a small stream or behind a sheltering point, while the quartz sand was largely worn and carried away by the currents of the sea.

Zircon is an almost constant minor accessory mineral in the crystalline rocks of this old shore and its extension westward, and in places it occurs in large masses. Near Gouldin post office, 10 to 15 miles southwest of the Ashland area, pieces of zircon 3 inches in diameter weathered out of pegmatite dikes have been noted on the surface. Massive zircon without crystal outline and measuring 6 by 4 inches has been observed in the pegmatites of Amelia County, Va. Similar dikes occur in the gneiss-granite complex of the Piedmont Plateau, forming the old shore line which extends entirely across Virginia from Maryland into North Carolina, roughly coinciding with the meridian of 78° 30'. It seems probable that similar zircon-rich rocks may occur at numerous points along this old shore line. Many zircon-bearing deposits may be covered by later sediments and some may have been removed by erosion, but it is probable that others, which may be richer or poorer, will be discovered along the contact of the granite and gneiss of the Piedmont Plateau with the overlying sediments of the Coastal Plain.

Zircon-bearing sandstone deposit.--The Ashland deposit has been described by Schaller, as follows:62/

A bed of zirconiferous sandstone is exposed about 3 miles west of Ashland, Va. The bed does not crop out as a continuous ledge, but is represented on the surface by isolated flat fragments or bowlders, only a few of which are as much as a foot long. The largest bowlder seen measures 26 by 15 by 10 inches; the average diameter of the bowlders is about 4 to 6 inches. These isolated fragments and bowlders are found in the clay, gravel, or sand soil for about a mile north and south and about 500 feet east and west. The vertical thickness of the zone containing these bowlders does not seem to be more than a few feet, although there is almost no evidence on this point. The zirconiferous bowlders seen on the surface would not weigh altogether more than several hundred tons.

62/ Schaller, Waldemar T., Work cited, pp. 20-21.

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The zirconiferous bowlders occur at the "fall line," or junction of the coastal sediments and the igneous rocks of the Piedmont, which are less than a mile west. The hard brownish bowlders are held to represent a local cementation of a soft sandy bed which was found in the lower part of a well 14 feet deep near the home of Benjamin Wright, 5/8 of a mile southwest of the Shelton home, where these hardened surface bowlders occur in greatest numbers. The sand in Mr. Wright's well contained 13 per cent of zircon. The hardened bowlders found on the surface for a distance of nearly a mile showed a greatly varying content of zircon, the maximum being 30 per cent.

The compact sandstone contains much ilmenite and quartz and smaller quantities of rutile, staurolite, kyanite, feldspar, and other minerals. All of it is cemented by brown limonite. The density of the sandstone is a good indication of its zircon content; for the pieces very poor in zircon weigh perceptibly less than those rich in zircon. A collection of 24 samples of the brown bowlders from the northernmost exposure contained only 0.5 per cent of zircon; 7 samples from another place yielded 3 per cent of zircon; 19 samples from another place gave 12 per cent of zircon; a compact brown bowlder near Mr. Wright's house contained 25 per cent of zircon; and the average content of 32 pieces of fine-grained sandstone from the Shelton farm contained 25 per cent of zircon. On the other hand, 17 samples of coarse-grained sandstone from the Shelton farm, similar in appearance to the fine-grained material except in the size of its particles, averaged only 1 per cent of zircon.

Ten samples of the clay dirt collected from the well on the Shelton farm, at 2-foot vertical intervals, contained zircon from a trace to nearly 0.5 per cent. Only three of the samples yielded more than 0.1 per cent of zircon, and five of the samples had less than 0.03 per cent.

The occurrence was thoroughly tested in 1912 by G. L. English, who sunk a number of pits on the Shelton farm. In one of these pits a solid bed of the zirconiferous sandstone was found 7 feet below the surface; in the other pits only isolated fragments of the hardened sandstone were found. There seems to be very little evidence of the existence of a continuous bed of this sandstone, short lenses a few feet in length seeming to be the general feature. Most of these lenses have been broken up into isolated fragments and bowlders, and there is almost no evidence of a continuous bed of this particular rock. Moreover, the diverse character and zircon content of the bowlders, as found, show that only a part of the deposit contains enough zircon to be considered a possible source of that mineral.

The very evidently stratified character of the bowlders, many of which have a distinctly layered structure, indicates that the local cementation extended for horizontal distances of about 10 feet

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or more. The problem of the presence or absence of a distinct well-defined bed a mile long can be solved only by a detailed study of the region, involving the sinking of numerous pits.

Zircon-bearing pegmatite deposits.--In the well-known pegmatites near Amelia, Amelia County, and near Gouldin, Hanover County, in the middle-eastern part of the Piedmont Plateau province, separated by a distance of approximately 40 miles, are large masses of zircon. According to Watson,[63] the features of special interest in connection with the pegmatites of the two localities are: (1) its occurrence in massive forms of unusual size, and (2) its association in the two places with an entirely different group of the rarer minerals, although the pegmatites of each area are of granitic composition. Zircon and apatite are the only rare minerals that have been found alike in the two areas, and so far as it has been determined the zircon is more abundant in the Hanover County deposit than in that of Amelia County.

The following descriptions (given in part) of the two areas are by Watson:[64]

> Amelia County area.--The pegmatite bodies occurring near Amelia County have long been known for the variety of rare minerals found in them, many of which were of unusual size. The dikes have been worked from time to time for a long period of years as a source of commercial mica and feldspar, and to a less extent of minerals for the gem trade.
>
> The country rock is a thinly foliated, moderately dark-colored, fine-grained biotite gneiss or schist, containing more or less muscovite. Where measured, the foliation strikes N. 25° to 30° E. and dips 40° to 50° N. W. Diabase dikes of Mesozoic age intrude the rocks in places. The pegmatite bodies are dikelike in form and nearly vertical, with the direction of trend doubtful. They cut across the foliation of the schists, and the large ones will measure more than 50 ft. across. They are cut by joints, but there is no evidence of schistose structure developed from metamorphism.
>
> The pegmatites are of granitic (acidic) composition, containing feldspar, including the potash varieties, orthoclase and green microcline, and the soda variety, albite, with quartz and muscovite, and a large number of rarer minerals. The principal rock-forming minerals are not uniformly distributed through all parts of the pegmatites, but their distribution is very irregular, first one and then another of these minerals predominating in different parts. The albite, occurring in splendid crystallizations as reticulated platy forms of bluish white to white color and frequently transparent, is of a high degree of purity. . . .

63/ Watson, Thomas L., Zircon-Bearing Pegmatites in Virginia: Am. Inst. Min. Eng. Bull. 115, July, 1916, p. 1238.

64/ Watson, Thomas L., Work cited, pp. 1237-1243.

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The texture of the pegmatites is granular consertal rather than graphic. Miarolitic cavities have been observed in some of the openings made in the pegmatites. One of these was of large size, the walls of which were lined with crystals of smoky quartz and pure white crystals of albite, some as transparent as glass.

The rarer minerals include representatives of five distinct chemical groups: (1) Halcids, including fluorite; (2) silicates, including garnet (spessartite), black tourmaline, beryl, helvite, allanite, and zircon; (3) niobates, including columbite; (4) tantalates, including microlite; and (5) phosphates, including apatite and monazite. With the exception of fluorite, tourmaline, and zircon, each of the minerals has been analyzed with the results shown below. Some of these minerals have been found only occasionally in the Amelia pegmatites and are very rare. Many of them attained unusual size, such as crystals of beryl 3 to 4 feet long and 13 inches thick, columbite in crystalline masses weighing 6 to 8 pounds, allanite crystals more than 15 inches long, microlite in masses up to 8 pounds in weight, and monazite in masses larger than those of microlite. Zircon has been noted in small crystals and in masses weighing several pounds. Stibnite and galena have been reported, but they are extremely rare and have not been seen by the writer. . . .

Hanover County area.--The zircon-bearing pegmatites of Hanover County form a part of the recently discovered but fairly well-known rutile area of Goochland and Hanover Counties, which lies about 25 miles northwest of Richmond. . . . The principal rock of the region is a gneiss of variable composition, chiefly micaceous (biotite and muscovite) and at times hornblendic, cut by numerous pegmatites, some of which are rutile-bearing, and a variety of basic igneous rocks. Microscopic study of thin sections of the gneiss shows it to conform in composition to an original acidic igneous rock of the granite type. The banded structure is secondary, developed by regional metamorphism. . . .

Zircon has recently been found associated with rutile in the pegmatites near Gouldin in the Hanover portion of the rutile area. The mineral has been found in irregular fragments and masses up to about 12 pounds in weight. One of the larger masses examined by the writer appears to have been broken from a large crystal of the mineral. Like the other constituents of the pegmatites, every specimen of the zircon studied shows mashing and squeezing from metamorphism. The color is irregular even in the same mass, ranging from reddish-brown through grayish to colorless. Although a chemical analysis of the zircon has not been made, laboratory tests carried out on a number of pieces of the mineral show it to be quite pure. The many pieces of the mineral found on the surface, due to the extensive weathering of the pegmatite bodies, encourage the belief that the mineral is by no means a rare constituent of the dikes in this area and may be found in quantity to be of commercial value.

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Lee,[65] in his discussion of hafnium-bearing minerals, stated that a hydrated zircon from Amherst County, first described by Mallett, was under examination.

Washington

Washington has many localities in which the presence of zircon has been noted, chiefly in black sands, old and present beaches, placer gravels, etc.[66] The individual localities, as listed by Day and Richards,[67] are far too numerous for citation here; the counties are as follows: Asotin, Chehalis, Clallam, Clarke, Douglas, Garfield, Okanogan, Pacific, Stevens, Thurston, and Whatcom. San Juan Island is included in the places noted by these authors.

Wisconsin

Gosreau, who investigated methods of ore treatment for the pegmatite deposits in north-central Wisconsin, in Marathon County, approximately 11 miles from the city of Wausau, has given the following report concerning the geology of the district, the character of the zircon, the nature of the tests made upon the ore, and the results deduced:[68]

> The zircon mineral and its associated minerals and rock structures, crystalline shape, and habits, are described by Weidman, from whose report the following descriptive data are taken:[69]
>
> The general geology of the district consists of igneous rocks of diorite, with syenite and pegmatite veins, more or less vertical, intruding the diorite rock masses. These veins are of varying thickness, not definitely known. The pegmatite is coarsely crystalline, a characteristic of these pegmatites. Several varieties of the syenite occur, as well as several mineral phases of the pegmatite. The quartz-pegmatite is composed of quartz and feldspar, and it is the quartz-pegmatite phase that carries the zircon. Other associated minerals are the oxides of cerium, thorium, tantalum, columbium, and yttrium. The syenite carries some small crystals of zircon, of purely mineralogical interest. The diorite does not carry any zircon, according to surface examinations.
>
> The system of pegmatite dikes or veins apparently has a width on the outcrop of about 1,300 feet, and the strike was followed for

65/ Lee, O. Ivan, Work cited, pp. 24-25.
66/ Morris, H. C., Work cited, pp. 9-13.
67/ Day, David T., and Richards, R. H., Work cited, pp. 1216-1220.
68/ Gosreau, R. C., Recovering Zircon from a Zirconiferous Pegmatite: Eng. Min. Jour.-Press, vol. 119, No. 10, Mch. 7, 1925, pp. 405-406.
69/ Weidman, Samuel, The Geology of North Central Wisconsin: Wisconsin Geol. and Nat. Hist. Survey, Bull. 16, Sci. ser. 4, 1907, 681 pp.

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about 2,000 feet. The strike of the outcropping pegmatite veins is northwest-southeast, but no data as to the probable dip are at this time available.

On the surface the pegmatite is much weathered, forming a residual soil from 6 inches to 3 feet thick, in which zircon crystals are found plentifully. Considerable float, in bowlders as large as 10 and 15 inches across, covers the area, these having been thrown in huge piles, so that the land could be farmed. These rock piles are from 75 to 100 feet long, 30 to 40 feet wide, and about 15 feet high. The bowlders furnished the supply of zircon for the milling and chemical treatment of the pegmatite to be described.

An analysis of the aluminous-zircon mineral, given by Weidman, follows:

Table I -- Typical Analyses

	1	2	3
SiO_2	28.87	30.89	31.01
ZrO_2	57.79	60.89	62.12
Al_2O_3	7.80	5.11	4.28
Fe_2O_3	4.47	1.54	1.21
H_2O (red heat)	1.61	1.41	1.76
H_2O (105 deg. C.)	0.43	0.56	0.24
Sp. Gr.	4.28	4.30	4.65
Color	Reddish-brown	Reddish-brown	Pale-yellow
Occurrence	Coarse pegmatite	Fine pegmatite	---

This zircon is high in alumina, accounting for the lower content of ZrO_2, and giving an average oxide content of only 60.3 per cent, against 67.1 per cent for pure mineral.

The apparent quantity of rock available and the fairly high purity of the mineral suggested that mining and concentrating into a product of sufficient richness for commercial uses might under favorable conditions be profitable.

A lot of 3,100 pounds of raw rock was crushed through a jaw crusher to $\frac{1}{4}$-inch and sampled carefully. The analysis showed 15.9 per cent of ZrO_2 and 26.4 per cent of $ZrSiO_4$. The $\frac{1}{4}$-inch rock was then ground sufficiently fine to release the zircon from the quartz-feldspar matrix, a minus-35- and plus-65-mesh product being desired, though the crushing and grinding equipment was not controllable to this degree of accuracy.

Water was added to make a 7 to 1 pulp, which was fed slowly to a Wilfley table, using a slight inclination and a long stroke, with plenty of wash water.

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. . . The silicate was calculated on a basis of 60.3 per cent oxide in the mineral, and no deduction was made for the alumina content, which was constant. Although the mineral is not pure zircon, the alumina content is not thought prejudicial to its ultimate use. I have attempted to use an aluminate bond and a zirconate bond for zircon, and the natural alumina content may have considerable value.

Concentration ratios: vanner concentrates, 12.5 to 1; vanner tailings, 12.2 to 1.

A pure concentrate rather than high recovery was here sought. Results should be better in a commercial mill. The products containing more than 30 per cent ZrO_2 seem to be suitable for a refractory material, especially the vanner products.

The specific gravities of the minerals involved are: Zircon, 4.0 to 4.7; quartz, 2.3 to 2.7; feldspar, 2.5 to 2.6.

The two vanner products were combined for the chemical treatment. This product averaged 51.1 per cent ZrO_2, thus being 84.8 per cent pure mineral. Considerable iron was also present, which was removed by chemical treatment, to make the following product:

	Per Cent		Per Cent
ZrO_2	57.34	Al_2O_3 (free)	0.65
$ZrSiO_4$	95.00	SiO_2 (free)	4.80
Fe_2O_3	0.30		

This final chemically treated product was dried and ground to 120 mesh. When ground, it had a full white color. Both the final product and the concentration products from this treatment of the raw pegmatite were studied, tested, and found suitable for the following uses:

1. Brick for iron, steel and glass furnace linings.
2. Crucibles, muffles, combustion tubes, insulating tubes.
3. Surface cement for covering other refractory brick, linings, and roofs.
4. Enamel pigment, for iron and steel covering enamels.
5. Added to enamel ware, silica and stoneware, to increase the elasticity and the strength.
6. To prevent devitrification in enameling.
7. Monolithic lining material for walls and hearths, and patch material for electric furnaces making steel, iron, ferroalloys, and brass.
8. Fused in the electric arc and reground, a refractory of high quality would result.
9. A base for making pure white zirconium oxide.
10. An ingredient in magnesia and alumina refractories.

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Wyoming

The black sands tested by Day and Richards[70] in the State of Wyoming revealed zircon to be present at Sherman and Keystone, Albany County; Atlantic City and South Pass, Fremont County; Buffalo, Johnson County; Green River, Sweetwater County; and in the Bald Mountain district.

Canada

Very large crystals of zircon, weighing as much as 15 pounds, have been found at Renfrew, Ontario, Canada. The supply is limited, according to Venable.[71] In the description of a new mineral, lyndochite, of the euxenite-polycrase group, from Lyndoch Township, Renfrew County, Ontario, Ellsworth[72] states that among the associate minerals crystal aggregates of zircon or cyrtolite occur the size of a fist.

Marden and Rich[73] report that zircon occurs in crystalline limestone at Grenville (Argenteuil County), Quebec. Zircon syenites exist in Ottawa County, Quebec.[74] In the limestone that surrounds the essexite of Mount Royal, at Montreal, Quebec, zircon is one of the minerals that result from the effects of pneumatolytic contact metamorphism.[75]

Mexico

Zircon is found in the meteoric iron of Toluca, district of Toluca, State of Mexico, Mexico.[76]

West Indies

In a geological survey report upon St. Vincent,[77] the smallest island of the Windward group of the Lesser Antilles, the author states that deposits of black sands, which consist principally of feldspar, mag-

70/ Day, David T., and Richards, R. H., Work cited, p. 1220.
71/ Venable, Francis P., Work cited, p. 18.
72/ Ellsworth, H. V., A New Mineral of the Euxenite-polycrase Group from Lyndoch Township, Renfrew County, Ontario: Am. Mineral., vol. 12, May, 1927, pp. 212-218.
73/ Marden, J. W., and Rich, M. N., Investigations of Zirconium with Special Reference to the Metal and Oxide: Bull. 186, Bureau of Mines, 1921, p. 5.
74/ Fox, Cyril S., Notes on Titanium, Zirconium, Cerium and Thorium: Trans. Min. Geol. Inst. India, vol. 20, pt. 3, Feb., 1926, Calcutta, 1926, p. 265.
75/ Gillson, Joseph L., Work cited, p. 194.
76/ Instituto Geologico de Mexico, Zircon ($ZrSiO_4$): Bol. 40, Catalogo sistematico de especies minerales de Mexico, Secretaria de Industria, Comercio y Trabajo, Mexico, 1923, p. 251.
77/ Earle, Kenneth W., The Geology of St. Vincent and the Neighboring Grenadines: Rept. on the Geol. of St. Vincent and the Neighboring Grenadines, Kingston, 1928, p. 5.

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netite, and ferromagnesian minerals, contain a little zircon. A particularly extensive deposit of this kind, about a mile long, occurs between Georgetown and Black Point.

SOUTH AMERICA

Brazil

General (Geological and Mineralogical)

The States of Sao Paulo and Minas Geraes (in the so-called Caldas region) yield the native zirconium oxide, and the States of Bahia, Espirito Santo, and Rio de Janeiro in the beach sands yield the silicate. A deposit of zirconium (about which little is known) is reported in the State of Goyaz, also, north of Minas Geraes.[78]

States of Sao Paulo and Minas Geraes.--The ore in the Caldas region, States of Sao Paulo and Minas Geraes, forms (according to a Brazilian Government Report) the following groups:[79]

1. Rounded pebbles containing 90 to 93 per cent of zircon in the form of dioxide (ZrO_2), known by the name "favas de zirconio."

2. Massive minerals, as zirkite, light-brown, or caldasite, dark-blue minerals, with a variable percentage of zirconium oxide, 73 per cent in the first mineral and 80-85 per cent in the second one.

3. A good method of enriching being employed, an ore with 80 per cent zirconium oxide (baddeleyite) is obtained.

Three different minerals enter into the composition of "Zirkite" (trade name) and caldasite: baddeleyite, zirconite, and orvillite, a new hydrosilicate of zircon.

The bearing rock is not well known, but the mineral is thought to be in intimate relation with nepheline-syenite rocks that contain eudyalite as a characteristic constituent.[80]

This Brazilian occurrence, which is the most extensive deposit of zirconium known, and which can supply industry for many years, is in a plateau region, partly in the State of Minas Geraes and partly in the State of Sao Paulo, approximately 130 miles north of the City of Sao Paulo. Venable describes the region as follows:[81]

78/ Cameron, C. R., American consul general, Sao Paulo, Brazil: Trade letter, May 23, 1930, to Philipp Bros. (Inc.), 233 Broadway, New York, Bur. For. and Dom. Com. file.

79/ De Oliveira, Euzebio Paulo, Zircon: Min. Res. Brazil, Servico Geol. e Mineral. do Brazil, Ministerio de Agricultura, Industria e Commercio, Rio de Janeiro, 1930, pp. 27-28.

80/ De Oliveira, Euzebio Paulo, Work cited, pp. 27-28.

81/ Venable, Francis P., Work cited, p. 19.

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The mountainous plateau has a main elevation of 3,600 feet. The surface is undulating, presenting differences in level from 300 to 600 feet. The whole area is bounded on all sides by ridges rising abruptly from 600 to 1,200 feet above the general level and forming a roughly elliptical inclosure, with a major axis of approximately 20 miles in length and a minor axis of 15 miles. The predominant rock of the plateau is phonolite.

States of Bahia, Espirito Santo, and Rio de Janeiro.--From Rio de Janeiro to Bahia, on the beaches of the States of Bahia, Espirito Santo, and Rio de Janeiro, zirconium occurs as sand mixed with silicates, principally in monazite sand. "Cusps of the beaches are protected on the north by granite headlands and bordered by Tertiary bluffs cut by various streams and lagoons, which furnish a constant wash of fresh material for the concentrating action of the tides, wave action, and trade winds, which latter are said to play an important part in the final result."[82] This zircon sand is found in large quantities near Victoria (State of Espirito Santo), where it has been mined.

The monazite sand is reported to contain about 63 per cent of the oxide, occurring as $ZrO_2:SiO_2$.[83] De Oliveira gave the following analysis in the Government report quoted in a preceding paragraph:[84]

	Per cent
Ilmenite and ferrominerals	14.2
Monazite	61.4
Zirconite	20.7
Quartz.....	3.7
	100.0

History of the Industry

The most important of the zirconium ores, baddeleyite, was discovered in 1892. It is not known when this ore was first mined. However, according to an American representative in Brazil,[85] the development, expansion, and retrogression of the Brazilian zirconium industry are closely allied with the World War." Before the war, when little interest was manifested by any one in zircon, the ore was shipped to Germany in ballast on homeward-bound vessels and used in the manufacture of gas mantles. In 1914, the German Government, which had been buying increasingly large amounts of sand, placed an order with Mr. Gordon, a producer, for 2,000 tons, at his price. This action of the German Government caused Mr. Gordon to make an investigation, the results of which convinced him that the Germans were obtaining from the sand a metal that formed the basis of extremely efficient

82/ Morris, H. C., Work cited, pp. 9-13.
83/ Cameron, C. R., Work cited.
84/ De Oliveira, Euzebio Paulo, Work cited, pp. 27-28.
85/ Dawson, Claude I., American consul general, Rio de Janeiro, Brazil: Trade letter, Jan. 26, 1929, to Sherlow Chemical Co. (Inc.), 136 Liberty Street, New York, N. Y.

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star shells and flares. Also, a few months after the beginning of the war, the British Government discovered the presence of zirconium in the metal of German guns. In 1915 the Brazilian industry was rendered inactive because of the readjustment of markets. From 1916 on exports were made to both England and the United States. As exports and production figures for these years are in almost every instance identical, reference is here made to the table of production in Bureau of Mines Information Circular 6455.

The following table of exports for 1927 and 1928, with countries of destination, is offered by Cameron[86]

Exports of zirconium minerals, 1927 and 1928

	1927		1928	
	Kilos	Milreis[1]	Kilos	Milreis[2]
Germany	8,000	18:000$	481,723	147:713$
United States	177,000	13:895$	254,000	76:200$
Great Britain	----	----	15,000	6:000$
France	24,950	2:125$	10,200	3:560$
Argentine	----	----	9,100	2:730$
Belgium	49,940	35:385$	----	----
Netherlands	800	320$	----	----
	258,690	70:225$	770,023	236:208$

1/ The Brazilian customs statistics do not distinguish zircon sand from zircon ore, so that there are no available data showing the exports of each.

2/ In 1927, the official rate of exchange was 8$457 and the value in dollars $8,303; in 1928 the rate of exchange was 8$363 and the value in dollars $28,244.

Dawson says[87] that, whereas the readjustment of the market conditions caused a decline in the production during the first few years of the war, high prices tended to expand the industry during 1917 and 1918. The comparatively heavy shipments in 1924 consisted of old stocks liquidated at good prices, Gaulin said[88] that in 1918 zircon sand was produced as a by-product of the monazite industry; that in 1925 the paralyzation of the monazite industry was reflected in the small exports of zircon; and that by 1925 no zircon sand was being mined. A 1929 report[89] is to the effect that small shipments of the oxide ore are being made from the port of Santos to New York and England, at a price of $60 a ton at

86/ Cameron, C. R., Work cited.

87/ Dawson, Claude I., Work cited.

88/ Gaulin, A., American consul general, Rio de Janeiro, Brazil, Zircon and Zirconia in Brazil: Consular Rept., Sept. 5, 1925, Bur. of For. and Dom. Com. file 184825.

89/ Dawson, Claude I., Work cited.

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Santos; that the zircon sand mines near Victoria are not being mined, the owners not being willing to resume operations until they are able to obtain an order for at least 250 tons, to be shipped in lots of 20 tons, at a quoted price of 600 milreis, f. o. b. Victoria, to be packed in sacks of 60 kilograms each. Dawson says:[90]

> It will be noted that the quotations given above are much higher than the average values per ton, as shown in the official export statistics. Either the official quotations given above are higher than the actual sales prices, or the consular invoice values do not properly indicate the actual value of the merchandise. This is all the more significant as the quotations f. o. b. Victoria given in September, 1925, are substantially the same as those quoted to-day, that is, 600 milreis per ton, while the average value per ton for that year is 274 milreis.

Mining

The deposits in the Caldas region, consisting of outcrops of zirconia, are mined by blasting with dynamite. From these deposits the ore is transported about 20 kilometers by carts, loaded on railway cars at Cascatas, and shipped over the Paulista Railway to Campinas, thence over the Sao Paulo Railway to Santos, a total distance of about 230 miles.[91]

Of the beach deposits (States of Bahia, Espirito Santo, and Rio de Janeiro), those near Victoria, State of Espirito Santo, mined as a by-product of the monazite industry, were surface-mined or quasi surface-mined, there being an overburden of about 2 meters of ordinary quartz sand and underlying layers of ilmenite, zircon, and monazite, in the proportions of 33 : 25 : 10, respectively. The product was easily mined. Electromagnetic separators were used to extract the three elements, first the ilmenite, then the zircon, and finally the monazite. The usual run of the mines was 90 per cent zircon. It is reported that the average contents of the zircon sand is 63 per cent oxide (ZrO_2:SiO_2).[92]

Owners

Deposits in the Caldas region are controlled by Byington & Co., Largo da Misericordia, 6, Sao Paulo, Brazil (New York office, 165 Broadway), in conjunction with David McKnight, Alameda Barros, 38, Sao Paulo. These deposits of zirconium dioxide ores are near Cascatas and Pocos de Caldas, in Minas Geraes, on the border of the State of Sao Paulo.

Another deposit in this region, at Sao Joao, State of Sao Paulo, was operated during the war. Because of legal differences, its lessors, Messrs. P. S. Nicholson & Co., of Rio de Janeiro, abandoned their interest in the mine; so it is no longer operated.[93]

90/ Dawson, Claude I., Work cited.
91/ Cameron, C. R., Work cited.
92/ Dawson, Claude I., Work cited.
93/ Cameron, C. R., Work cited.

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The monazite deposits near Victoria, State of Espirito Santo, are owned by Messrs. P. S. Nicholson & Co., Rua Theophilo Ottoni, 45, Rio de Janeiro (S. R. Scott & Co., 31 Pine Street, New York City, American agents), and John Gordon, Rua Visconde Itaborahy, 75, Rio de Janeiro, Brazil.[94]

Cost of Production and Shipping

According to Dawson,[95] no information is available concerning the cost of production of zirconium ore mined in Sao Paulo. The cost of production of zircon sand (near Victoria, State of Espirito Santo) was reported in the latter part of the year 1927 to be as follows:

	Cost per ton in milreis
Cost of production 22$000 per bag of 60 kilograms--16¼ bags per ton--equal to	357$000
Transportation to dock Victoria	44$000
Cost of sacks (at 2$000)	32$500
Export tax	10$000
	443$500

	Cost in dollars
Cost of production in dollars at exchange of 8$500 per dollar	$52.18
Freight to New York	10.00
Miscellaneous shipping charges	2.00
	64.18

British Guiana

Concentrates from placers in the Berbice district, of British Guiana, contain a small proportion of zircon and a high proportion of rutile. Small concessions have been granted to enable further prospecting to be done, but no new developments have been recently recorded.[96]

94/ Dawson, Claude I., Work cited.
95/ Dawson, Claude I., Work cited.
96/ Bulletin of the Imperial Institute (London), Recent Research on Empire Products; Mineral Resources, British Guiana: Vol. 27, No. 1, London, 1929, p. 191.

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AFRICA

Gambia

In the report[97] of a geological survey of the Gambia (British West Africa), the description of the cliff and well sections reads, "Heavy minerals are very scanty, except in the grit and conglomerate of the Upper River. They consist chiefly of ilmenite, magnetite and other iron oxides, and zircon, with tourmaline, staurolite, and rutile in much smaller quantities.

In the 21 concentrates obtained by panning material from gutters and streams, in which there appeared to have been some concentration of heavy minerals by nature, magnetite and ilmenite were the most abundant, with zircon second.[98]

Gold Coast

A geological survey bulletin of the Gold Coast (British West Africa)[99] lists zircon with the minerals most frequently found in concentrates obtained by panning the gravels and sands of the country.

Madagascar

A map accompanying a Government report of Madagascar[100] indicates zircon deposits at and to the east of Ambalavara, Beforona, and Vatomandry, which are near the east-central coast; also at Andakatohitsoka and to the east of Fianarantsoa, in the neighborhood of Ampanobe and Ambalavao, the latter places all being in the southeastern part of the island.

Zircon, occurring rather abundantly in Madagascar, is found in pannings, for the most part, in the form of transparent or slightly colored crystals, having a very bright luster. It is found likewise in the many alluvials of the island in the form of crystals, square or octahedral in form. The workable deposits known at the present time are those located in the vicinity of Befrona, of which M. Barbe is the proprietor, and those to the west of Fianarantsoa, of which M. Gauge is the proprietor. The zircon exported from Madagascar assays 60 to 65 per cent; some crystals, however,

97/ Cooper, W. G. G., Report on a Rapid Geological Survey of the Gambia, British West Africa: Gold Coast Geol. Survey Bull. 3, London, 1927, p. 15.

98/ Cooper, W. G. G., Work cited, p. 19.

99/ Kitson, A. E., Minerals in Concentrates; Outlines of the Mineral and Water-Power Resources of the Gold Coast, British West Africa, with Hints on Prospecting: Gold Coast Geol. Survey Bull. 1, 84 Pretoria Road, Streatham, SW., 1923, p. 40.

100/ Bulletin des Mines de Madagascar, A Propos du Zircon: Bull. 12, Dec., 1923, Direction des Mines, Gouvernement General de Madagascar et Dependances, Tananarive, 1923, pp. 217-218.

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have shown by analysis 90.7 per cent. The difference, therefore, between this zircon and that from Brazil lies chiefly in mechanical preparation.

Lacroix discusses the workable deposits (in which it is estimated that some thousands of tons are available), mentioned in the preceding paragraph, as follows:[101]

> M. Barbe reported that he can produce 15 to 30 metric tons of zircon monthly from gold-bearing gravels on the Fanavana, a small branch of the Beforona River. The zircon consists of small brown octahedrons, 1 to 8 millimeters, or 1/24 to 1/3 inch, in diameter.
>
> The Beforona deposit is near the railroad leading to Tanarive.
>
> M. Gaugé discovered, southwest of Solila, zircon crystals, 15 centimeters (6 inches) long, weighing several kilograms. M. Saulnier, a coproprietor, says that the mineral is found over 15,000 hectares to the north and south of Mananantanana, between the Mananbovona and the massif of Ingaro, notably at Mount Ampanobé.
>
> The zircon is found in great abundance. The beds are 4 meters deep. The zircon exists on the surface in a state of concentration; but the lowness of the grade is compensated for by the great extent of the beds. The perfection of form and the sharpness of the angles of the crystals indicate an alluvial deposit. Indications are that the deposit in place is a pegmatite.
>
> Transport from the Mananantanana offers much difficulty.

With respect to the gem grade of zircon, Lacroix says[102] that zircon crystals resembling those of Ceylon occur in the region of Itrongay, where he found two transparent specimens: one a violet stone, resembling axinite in color, perfectly clear, weighing 13 carats; the other a stone of greater size, but a bit frosty in appearance.

The reddish-orange crystals of zircon collected in the basaltic alluvials of Ankaratra only occasionally furnish usable stones.

Namaqualand

Rogers,[103] in giving his results of the microscopic study of 200 rocks of Namaqualand (German Southwest Africa) reports zircon in the norite, in the augite-diorite, in the mica diorite, and in the granite rocks.

101/ Lacroix, A., Les Industries minérales non métallifères à Madagascar: Paris, 1920, pp. 52-58.

102/ Lacroix, A., Les Pierres de Madagascar; Gemmes pierres d'ornementation, pierres d'industrie, Paris, 1921, p. 36.

103/ Rogers, A. W., The Nature of the Copper Deposits of Little Namaqualand: Anniversary Address by the President; Minutes of the Proceedings of the Geol. Soc. of South Africa: Proc. Geol. Soc. South Africa, Jan. to Dec., 1916, Johannesburg, 1917, p. 22.

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Nigeria

Northern Nigeria.--Prof. Wyndham Dunstan has made a number of surveys of the minerals of Northern Nigeria. The surveys were made of the concentrates of river beds for the purpose of detecting monazite and thoria chiefly, but the presence of zircon is reported in many of the localities studied.104/ The reports are far too detailed for even a digest here.

Southern Nigeria.--Under the heading of "Concentrates," zircon is mentioned as one of the stones of the river beds in a number of reports made by Professor Dunstan upon mineral surveys made of Southern Nigeria. (The concentrates were examined for their monazite and thoria content chiefly.) These reports, beginning in 1906, cover a number of years and are rather detailed.105/

Nyasaland

Three reports by Dunstan106/ record the occurrence of zircon in the Protectorate of Nyasaland (British Central Africa).

Rhodesia

General.--With respect to zirconium-bearing ores in Rhodesia in general, Zealley has reported as follows:107/

> Baddeleyite is not known to occur in Rhodesia. Zircon is of such widespread occurrence that if granite soil in any part of Rhodesia be panned, a tail of minute gray or reddish-brown zircon crystals will be noted; whilst pannings of the sand in the beds and banks of granite spruits will afford a much larger concentrate. There are such enormous tracts of granite in Rhodesia that the mineral could be recovered in large quantities. Two occurrences examined by the writer in 1917 appear to be worth commercial investigation. These are at Hillside, Bulawayo, and in the stream courses around Rusape. The Hillside syenite contains much more zircon than most granite rocks in Rhodesia; moreover the mineral appears in much stouter crystals--they may be as big as 1/8 inch; they are lustrous and generally reddish-brown, but partly colorless like quartz.

104/ Dunstan, Wyndham, Reports on the Mineral Survey of Northern Nigeria: Colonial Repts., Misc., 1904 to 1907, inclusive, Imperial Institute, London.

105/ Dunstan, Wyndham, Reports on the Mineral Survey of Southern Nigeria; Colonial Repts. Misc., 1906 to 1914, inclusive, Imperial Inst., London.

106/ Dunstan, Wyndham R., Report on the Results of the Mineral Survey: Colonial Repts., Misc., Nos. 48, 60, and 80, 1906-7, 1907-8, 1908-9, London, 1908, 1909, and 1911.

107/ Zealley, A. E. V., Zirconium Ore: Rept. Rhodesian Resources Comm. 1921, Bulawayo, 1921, pp. 130-131.

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> Specimens and information from Rusape indicate that zircon is an abundant constituent of granite sands and spruits in that region. The concentrates contain corundum, magnetite, ilmenite, scheelite, epidote, haematite, hornblende, tourmaline, sphene, rutile, and several other minerals, all in small quantities except the iron minerals, which could be removed by magnetic concentration. * * *

Southern Rhodesia.--Small quantities of ilmenite, zircon, and rutile are present in the concentrates of ore from Eileen Alannah mine, as ascertained by analyses. The mine Eileen Alannah is northeast of Gatooma, in the Eiffel Flats group of mines. The general description of the region in which this mine is located is that it is east of Gatooma and that it lies east of the Bulawayo-Salisbury Railway line, which runs in a northeast direction from Umswesve Siding, through Gatooma, to Hartley.[108]

Zircon is mentioned in a discussion of the petrography of the greenstone schists (under which term are grouped a number of metamorphic rocks, composed largely of hornblende) of the Enterprise Mineral Belt (Enterprise is a popular name for the farming and mining district situated directly east of Salisbury). The mineral belt is a strip of country extending east from Salisbury for about 35 miles, and measuring approximately 8 miles from north to south. The mineral belt forms part of the Salisbury mining district.

A sample of epidiorite with the massive type of hornblende from a hill 3/4 mile west-southwest of Chishawasha Mission contains regular inclusions of quartz, as well as of apatite and zircon, the last-named being surrounded by pleochroic haloes. On Father Hartman's farm the proportion of zircon is epidiorite was high.[109]

In a description of the geology of the diamond-bearing gravels of the Somabula Forest, under the heading "Karroo System," under the subheading "Mineralogy of the Concentrates," is the following:

> Zircon is an uncommon constituent of the concentrates. It forms pale chocolate-colored crystals, with pyramidal cleavage. Zircon commonly occurs in Rhodesian granites, notably in the neighborhood of Rusapi.

Somabula Forest forms a narrow belt 1 to 10 miles wide, stretching in a northwesterly direction for a distance of 70 miles and more, its range being controlled by the distribution of the Somabula beds. The part of the Somabula Forest dealt with in the report lies between 19° 20' and

108/ Zealley, A. F. V., Preliminary Report on the Geology of the District East of Gatooma: Southern Rhodesia Geol. Survey Bull. 1, Bulawayo, 1913, p. 19.

109/ Maufe, H. B., The Geology of the Enterprise Mineral Belt: South Africa Geol. Soc. Bull. 7, Salisbury, 1920, pp. 14 and 17.

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19° 50' south latitude and between 29° 30' and 29° 50' east longitude. (For a fuller description, see pages 9 and 10 of the article referred to in thd footnote.)110/

Senegal

Black, fine, and heavy sands on the coast of the Senegal (French West Africa), called ilmenite sands, and generally sold for their titanium content, in some places contain more zirconium than titanium, the average in one concession being 29 per cent zirconium and 28 per cent titanium.

These sand deposits are known to occur on the ocean beach in the vicinity of Dakar (at Rufisque, 15 kilometers across the bay from that city, and at Joal, about 100 kilometers south of Dakar); south of the village of Diakonar, in the vicinity of Bargny Guedje, Diogue, Thies, and St. Louis; and on the borders of Matam and Bakel.

Sierre Leone

A Government report of the Protectorate and Colony of Sierra Leone (British West Africa)111/ states that a few small brilliant crystals of zircon, as well as corundum and sapphire, were found in the gravels of the Little Scarcies River, for a few miles below the conjunction of this river with the Mabole River. The principal minerals of these sands, however, were rutile and ilmenite.

Uganda

The Uganda Geological Survey reports112/ that zircon occurs widely but is abundant in only one area in the Uganda Protectorate (British East Africa).

As the result of a geological investigation of a portion of the northern spur of Ruwenzori, principally on the western side of the mountain (from the Karimi River in a southwesterly direction to the Lamia River), but also in a small area on the eastern side of the mountain (from the Mpanga River in a southwesterly direction to the Nyabuswa River), and also several miles out from the mountain foot in Bwamba Province, the report was that the gravels from nearly all the streams and valleys yield very large concentrates, composed of coarse subangular magnetite and haematite, with a smaller amount of garnet, zircon, and other minerals.113/

110/ Macgregor, A. M., The Geology of the Diamond-Bearing Gravels of the Somabula Forest: Southern Rhodesia Geol. Soc. Bull. 3, Salisbury, 1921, p. 26.

111/ Report of the Geological Department for Part of the Year 1927 and for the Year 1928, Geological Department of the Colony and Protectorate of Sierra Leone, Freetown, 1929, pp. 14-15.

112/ Uganda Geological Survey Annual Reports, 1920 and 1925.

113/ Combe, A. D., Field Work--Northern Spur of Ruwenzori and Part of Bwamba, May 29 to August 19: Ann. Rept. Geol. Survey Dept., 1924, Uganda Protectorate, Entebbe, 1925, p. 6.

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Many of the concentrates from streams in the Province of Karamoja show grains that are easily recognizable as zircon. The grains are bright in luster and are either colorless or pinkish or pale-brown in color. Many of them are crystalline in form.[114]

Hirst reports[115] that three distinct habits of zircon occur in the valley of the Kafu River, and that apart from gold it stands second in abundance among the minerals in the normal concentrates.

Union of South Africa

General.--Lindgren, in a discussion of diamonds in his work on mineral deposits,[116] lists zircon with other minerals found in the blue ground of the Kimberley pipe in the Kimberley diamond field. The blue ground is the still unoxidized layer under the decomposed serpentine, or yellow ground, which is near the surface.

The Kimberley diamond field in South Africa lies in the northern part of Cape Colony and the adjacent part of the Orange Colony. Another district centers at Jagerfontein, in the Orange Colony; still another centers at the Premier mine, near Pretoria, in the Transvaal.

Cape of Good Hope.--In wash from molteno beds (as shown by a specimen from Molteno) the diamonds are accompanied by red garnet, rutile, and numerous other minerals, all of a size similar to that of the diamond, the zircons, anatases, and rutiles being fresh and sharp. Zircon is plentiful in little prisms, terminated at both ends, and having very strong black borders.[117]

In a description of the geology of the districts of Prieska, Kenhardt, and Carnarvon, Rogers and Du Toit,[118] in discussing the Marydale beds of the Kheis Series, mention zircon in a gray schistose rock formed of quartzite, biotite, sillimanite, magnetite, and a little feldspar, on Lower Rooi Puts, in the Rooi Puts belt. Grains of zircon were observed in the interstitial matter, together with albite, microline,

114/ Simmons, W. C., Laboratory Work; Rare Earth Minerals: Ann. Rept. Geol. Survey Dept., 1926, Uganda Protectorate, Entebbe, 1927, p. 35.

115/ Hirst, T., Summary of Work Carried out in the Kafu Valley in 1926: Ann. Rept. Geol. Survey Dept., 1926, Uganda Protectorate, Entebbe, 1927, p. 17.

116/ Lindgren, Waldemar, Mineral Deposits: 2d ed., McGraw-Hill Book Co. (Inc.), New York, 1919, pp. 787-788.

117/ Schwarz, Ernest H. L., Diamonds from the Molteno Beds: Trans. Geol. Soc. South Africa, vol. 19, Johannesburg, 1916, pp. 33-35.

118/ Rogers, A. W., and Du Toit, A. L., Geologic Survey of Parts of Kenhardt, Prieska, and Carnarvon: 14th Ann. Rept. Geol. Comm., 1909, Cape of Good Hope Dept. of Agriculture, Cape Town, 1910, pp. 9, 27, and 42.

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quartz, colorless garnet, muscovite, biotite, and magnetite, in the mass of pebbly grit and quartzite lying in the gneiss, partly on Piet Ekstеen's Kuil, and partly on Piet Rooi's Puts.[119]

The region described extends from the Orange River below the Priesha boundary to Upington and southwards to the vicinity of Carnarvon. The Hartebeest and Zak Rivers form the western limit from Staan-still-en-afspring on the Zak to Vyf Beker on the Hartebeest. From the farm (just named) on the Zak the boundary runs through Verneuk Pan past Zwart Kop, Hartog's Kloop, Boter Leegte, and Meintjes Kloop to the neighborhood of Carnarvon, thence to Victoria West and Van Wyks Vlei, across the Kaaien Bult to Nels Poortje, along the southwestern flank of the Kaaien Hills to Karree Leegte and across the hills to the Orange River on Uit Draai.

In a description of a petrological examination of the volcanic rocks of Matatiele Division, East Griqualand, Schwarz reports the presence of zircon, as follows:[120]

1. In red bed between the lavas, top of Drakensberg, on Eyrie.
2. In siliceous rock interbedded in lava, top of Drakensberg.
3. In volcanic breccia, neck on the farm N'Quatsha.
4. In volcanic neck, filled with agglomerate, on the farm N'Quatsha.
5. In the cave sandstone from N'Quatsha's Nek road.

N'Quatsha and Eyrie are two of the volcanoes the lava flows from which form the crest of the Drakensberg Range.

The following information has been supplied by the inspector of mines, Pretoria district, with reference to the availability in the Union of certain minerals for use in the manufacture of cheap jewelry:[121] Clear zircons up to several hundred carats in weight occur in large quantities on the surface of the Zibare mine, in the Carnarvon district of the Cape Province. The quantity is so great that they probably could be produced at the price of 2s. or 3s. a carat.

Transvaal.--In a discussion of the corundum fields in the northern and southern Transvaal, under the heading "Mineralogy of the Deposits," Hall says: "Rutile and zircon were found only in thin sections, the former in small regular deep-brown crystals in the ruby-disthene rocks from Mashishimale, Malelane, etc., the latter as inclusions in biotite of the Palmietfontein corundum reef."[122]

119/ Rogers, A. W., and Du Toit, A. L., Work cited, p. 42.

120/ Schwarz, Ernest H. L., Petrological Examination of the Volcanic Rocks of Matatiele, Griqualand, East: Ann. Rept. Geol. Comm. 1902, Cape of Good Hope Dept. Agriculture, Cape Town, 1903, pp. 94-96.

121/ Trevor, T. G., The Common Gem Stones of the Union: South African Min. Jour., vol. 27, Johannesburg, Ja. 26, 1918, p. 486. (No. 1374.)

122/ Hall, A. L., Corundum in the Southern and Eastern Transvaal: Geol. Survey Mem. 15, Union of South Africa Dept. of Mines and Industries, Pretoria, 1920, pp. 38-39 and 136.

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Special mention was made by the same author[123] of minute inclusions of zircon carried in plagioclase (andesine), a deep-greenish biotite in the Palmietfontein "reef" in Palmietfontein No. 374 corundum mine, 12 miles southwest of Louis Trichardt, Zoutpansberg district (northern Transvaal), in the plateau region west of the Pietersburg-Messina Railway.

Zircon is a fairly constant constituent of the banket, a South African mining term for beds of auriferous conglomerate, chiefly occurring in the Witwatersrand goldfields. (The Witwatersrand is a chain of mountains in the Transvaal from which 42 per cent of the world's gold is produced.) Zircon can be observed in about 20 per cent of the microscopic sections of the rock. Frequently the crystals exhibit prismatic and pyramidal faces. Others are irregular in form and fragmentary in appearance. The crystals, too, occasionally show rounding of the edges. The average length of the crystals is 0.2 millimeter, and their thickness is about two-thirds or one-half of the length. They are transparent and vary in color from almost colorless to pink, sometimes having a brownish tint. The crystals are conspicuously zonal in character. Zircons are found in the quartzite also, associated with the banket, though apparently in much less quantity.[124]

In a description of the Salt Pan on the Farm Zoutpan, No. 467, north-northwest of Pretoria (the Pan is a remarkable, flat-bottomed, crater-like depression within circular rims of red granite that rises in the form of a low range of bush-clad hills, about 25 miles northwest of Pretoria), Wagner says[125], that underneath each trona bed (of which there are sometimes five) there is a layer of mud or clay, in which small grains of zircon and rutile were noted. The crude trona contains appreciable quantities of organic matter, sodium chloride, and insoluble material.

At Gibeon (Gibeon district) and Mukorub (Berseba district), bright grains of zircon occur in the Gibeon and Mukorub pipes, where they have been mistaken for diamonds.[126]

Zanzibar

In the Zanzibar Protectorate (British East Africa), in the sands of varying grades and nature in the different strata of the Pemba Series and the upper portions of the Zanzibar Series, which contain high percentages of iron, zircon, ilmenite, etc., are frequently present.

123/ Hall, A. L., Work cited, p. 89.

124/ Young, R. B., Further Notes on the Auriferous Conglomerates of the Witwatersrand, with a Description of the Origin of the Gold: Trans. Geol. Soc. South Africa, vol. 12, Johannesburg, 1909, pp. 84-85.

125/ Wagner, Percy Albert, Some Problems in South African Geology: Proc. Geol. Soc. South Africa, 1917, Johannesburg, 1918, pp. 30-33.

126/ Wagner, Percy Albert, The Geologic and Mineral Industry of South West Africa: Geol. Survey Mem. 7, Mines Department of Union of South Africa, Pretoria, 1916, p. 72.

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According to an official report, so far the zircon has been considered only as prejudicial to the economic use of the sands as glass or molding sands.[127]

ASIA

Ceylon

An American representative in Ceylon,[128] after consultation with the Government mineralogist and a local gem expert, reported that although zirconium ore is found in large quantities in the island it has never been exported. Zircon is found in commercial quantities in the black sands of the sea beach, but it would not be practicable to collect the mineral on a large scale. No mention of exports of zirconium ore is made in the customs returns of Ceylon. Another representative[129] states that gem stones are shipped to Europe and America, the best stones being exported and the inferior ones being sold locally and in India.

Most of the literature concerning the zirconium of Ceylon relates to the gem grade of zircon, which is to be discussed at some length in a forthcoming information circular upon the zircon. In brief, the streams flowing through the Balangoda, Rackwana, and Ratnapura districts, in the central part of southern Ceylon (half-way between the city of Kandy and the southern shore of the island), yield the principal supplies of the gem stones.[130] At Matara, near Dondra Head, at the extreme point of the island, zircon is found in colorless individuals that are sufficiently large to be cut and employed in jewelry, being known in trade as Matara diamonds.[131]

Although the southwestern part of Ceylon, where zircon is a very common accessory constituent in the rocks along the coast, is the principal zircon-bearing region, the mineral is very common in all the gneisses of the crystalline area, and gneisses underlie a very large part of the island. The zircon appears in thin sections of the rock in the form of small rounded individuals or in minute prisms, having rounded edges.[132]

Fox reported the existence of baddeleyite at Rakwana, Ceylon.[133]

127/ Stockley, G. M., Report on the Geology of Zanzibar Protectorate: Govt. Rept., March, 1928, pp. 102-103.

128/ Turner, Mason, American vice consul, Colombo, Ceylon: Trade letter, April 27, 1925, Bur. For. and Dom. Com. foreign file.

129/ Vance, Marshall M., American consul, Colombo, Ceylon, Report on Mineral Deposits and Industries in Ceylon for the Year Ended December 31, 1921: Consular Rept., Aug. 2, 1922, Bureau of Mines foreign file 4138.

130/ Adams, Frank Dawson, A Visit to the Gem Districts of Ceylon and Burma: Ann. Rept. Smithsonian Inst., 1926, 1927, pp. 297-318.

131/ Adams, Frank Dawson, The Geology of Ceylon; Geology: Canadian Jour. Res., vol. 1, No. 5, Nat'l. Research Council of Canada, Ottawa, Nov., 1929, p. 461.

132/ Adams, Frank Dawson, The Geology of Ceylon; Minerals of Economic Value, Gems: Canadian Jour. Res., vol. 1, No. 6, Nat'l. Research Council, Ottawa, Dec., 1929, p. 508, (Also, The Geology of Ceylon; The Quartz-Mose Biotite Gneisses of the Ordinary Type, vol. 1, No. 6, p. 467.)

133/ Fox, Cyril S., Work cited, p. 265.

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A mineral survey of Ceylon was instituted in 1902, at the suggestion of the Director of the Imperial Institute, to examine the existing deposits of minerals of economic importance and to search for new deposits, in order to pave the way for commercial development. The results of the survey are summarized in the following paragraph.134/

1. Shore deposits of the West and South Coasts.
   (1) Shore deposits from Colombo northwards.
   From Colombo to Dutch Bay, garnet, zircon, and rutile were the common associates of the monazite in the nambu (a natural concentrate of heavy minerals; also employed to denote the residue of heavy minerals left after washing the gem gravel and removing valuable gems).
   From Puttalam northwards zircon was found to be rather less common.
   (2) Coast belt between Colombo and Hambantota.
   A sample of concentrate from the fourth bay south of Bentota River (examined by the Imperial Institute), consisting chiefly of monazite and ilmenite, yielded some zircon and rutile. A concentrate from Kaikawala, consisting chiefly of monazite, yielded small amounts of zircon, with other minerals.

2. Alluvial deposits in the Ratnapura district.
   (1) Kalu Ganga Valley.
   Seventeen samples of concentrates from sands obtained from drilling in the bed of the Kalu Ganga. Although ilmenite and garnet were the chief stones, some zircon (with other minerals) was found.
   (2) Gravel of the We Ganga.
   Fourteen concentrates obtained by boring in the river beds and adjacent flats, while consisting chiefly of ilmenite, carried zircon as well as other minerals. Dredging in the We Ganga showed the same minerals in practically the same proportions.
   (3) Other deposits.
   A promising nambu, made up of zircon, garnet, spinel, tourmaline, and corundum, found in a drill bed sunk in Niwitigala village, in the Dela district. Gravel is fairly extensive here.

134/ Bulletin of the Imperial Institute (London), Reports of Recent Investigations at the Imperial Institute; Recent Work on Monazite and Other Thorium Minerals in Ceylon: Vol. 14, No. 3, July-Sept., 1916, London, 1916, pp. 321-369.

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3. Gravels of the Kelani Ganga.

(1) Between Madagoda and Pugoda.

Sixteen concentrates examined from the Pugoda Ganga bore holes: ilmenite predominant mineral; zircon and others in comparatively small amounts.

(2) Between Pugoda and Malwana.

Nine concentrates. Practically as above.

4. Gravels of the Sitawaka Ganga.

Twenty-seven concentrates examined by the Imperial Institute. Ilmenite predominant. Zircon included with other minerals present.

5. Nuwara Eliya district.

(1) Nuwara Eliya Plains.

The quartz gravel yielded a little black tourmaline and zircon crystals.

(2) Moon Plains.

A remarkable nambu, rich in monazite, opaque corundum, zircon, and zenotime, with a few gem stones, was obtained from a small flat on the Rifle-range Stream, near the head of its gorge. The dike rock is an orthoclase pegmatite. Samples (taken at one time) showed 12 grams of zircon a metric ton. Zircon crystals can be picked out of the decomposed rock by crumbling up the lumps of kaolin. In the gravels yellow transparent zircons are common.

Samples taken at another time showed that the concentrate from pegmatite consisted chiefly of zircon, with some biotite, ilmenite, and garnet.

The Magoda Oya gravels yield a nambu rich in corundum and chrysoberyl, with zircon and black tourmaline. Concentrate from the vicinity of Nuwara Eliya showed small amounts of zircon.

(3) Elk Plains.

The zircon found here (not in valuable amounts) differs from that in the Moon Plains pegmatite in having a brownish-pink color.

(4) Horton Plains.

As on the Elk Plains, pink zircon accompanies the monazite.

6. Thorianite and thorite deposits in the Bambarabotuwa, Denawak Ganga, and Walawe Ganga districts.

(To revive interest in the production of thorianite, headmen were informed in 1915 of the increase in the value of the mineral, and efforts were made to examine samples.)

(1) Bambarabotuwa district.

Prospecting on the Kuda Pandi Oya showed thorianite in all the veins as the principal accessory mineral, with

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ilmenite next in importance, and small quantities of thorite, monazite, and zircon.

(2) Denawela Ganga district.

Dredging in the Denawela Ganga along the steeper courses of the stream yielded well-rolled fragments of gem minerals, chiefly zircon and spinel, with a trace of thorianite, at a depth of 4 to 5 feet.

(3) Walawe Ganga district.

A number of mineral specimens from Walaweduwa, examined by the Institute, proved to be zirkelite, containing 36.2 per cent zirconia, thoria 17.4; titanium dioxide 24.6; and lime 6.7.

(4) Thorianite at Niralgama.

Niralgama, 5 miles south of Ratnapura. In addition to thorianite (predominant) were found thorite, fergusonite, rutile and zircon.

(5) Prospecting for thorium minerals in the Yalkumbura district.

An outcrop of pegmatite, with large phlogopite crystals, occurs near the head of the dry dola, and pannings from the surface gave abundance of fine monazite. Material from the body of the vein gave abundance of zircon. Specimens from Yalkumbura examined by the Imperial Institute showed zircon from pegmatite. A concentrate consisting almost wholly of zircon, contained some quartz, monazite, and small amounts of rutile, ilmenite, hornblende, and magnesite. The monazite amounted to about 4 per cent. Zircon was present also in monazite from gullies and in the monazite from pegmatites; the thorite from gullies consisted chiefly of zircon and spinel, with some thorite and rutile--13.66 per cent of thoria.

India

Fox says[135] that zircon is a common accessory mineral in many granitic and gneissose rocks in India. Large crystals are sometimes found in certain pegmatites that contain rare-earth minerals. Zircon concentrates, however, are most commonly found in the river sands and in the beach sands in the neighborhood of zircon-bearing rocks.

Travancore.--The principal deposit of zircon in India and the only one ranking as a commercial source of the mineral is in Travancore. The Travancore beach deposits, which are now exploited chiefly for their ilmenite, contain appreciable quantities of zircon, as well as monazite, the zircon carrying 62 to 63 per cent of zirconium oxide, the ilmenite 50 to 53 per cent titanium oxide, and the monazite 8.50 to 9.20 per cent thorium oxide. These deposits are renewed several times a year by the sea, along an extent of 79 miles.

135/ Fox, Cyril S., Work cited, pp. 257-258.

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The output of zircon, obtained as a concurrent product in the collection of ilmenite and monazite in Travancore State, decreased from 1,465 tons, valued at £8,129, in 1927, to 885.2 tons, valued at £4,267, in 1928, in spite of a conspicuous increase in the production of ilmenite.136/

The company that is mining the Travancore deposits is The Travancore Minerals Co. (Ltd.), 52 Queen Victoria Street, London, England, which has a local office at Colachel, South Travancore, India.

For a description of the Travancore beach sands (written especially with reference to their monazite content), see the footnote reference.137/

The following notes are, for the most part, taken from transactions of the Geological Institute of India.138/

Bihar and Orissa.--Large clusters of dark-brown crystals of zircon have been found in the pegmatite of Abraki Pahar, in the Gaya district. In that locality it is associated with pitchblende.139/

Burma.--Appreciable percentages of zircon crystals were found in an ilmenite sand, containing monazite, from Upper Burma. It is understood that the sands are attractive for their monazite content. The zircon and ilmenite would be useful by-products.

Chitral.--Zircons have been found in the magnetite-ilmenite sands of the streams of Chitral. The quantity and quality of the material are not very attractive, and the localities in which it is found are inaccessible.

Madras.--Madras State is by far the most important area in India with respect to the rarer minerals, titanium, zirconium, cerium, and thorium. Zircon has been located in the nepheline syenites near Kangayam, in the Coimbatore district, in the pegmatites at Kadavur of the Trichinopoly district, and in the Seitur graphite mine at Ramnad. A hydrated form of zircon (resembling cyrtolite), containing a small percentage of uranium, is associated with samarskite in the Nellore district. Bohm140/ reports zircon in the Province of Circars, on the eastern coast of the Madras Presidency.

136/ Records of the Geological Survey of India, Zircon: Vol. 62, pt. 3, 1929, Calcutta, 1929, p. 332.

137/ Tipper, G. H., The Monazite Sands of Travancore: Rec. Geol. Survey of India, vol. 44, pt. 3, Nov., 1914, pp. 186-196.

138/ Fox, Cyril S., Work cited, pp. 257-258.

139/ Records of the Geological Survey of India, Pitchblende: vol. 44, pt. 1, May, 1914, pp. 24-26.

140/ Bohm, C. Richard, Das Aufschliessen der wichtigsten Mineralien; Zirkon: Die Darstellung der seltenen Erden, Leipzig, 1905, pp. 108 and 116.

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With respect to the gem grade of zircon, Brown[141] reports that fine crystals come from an unknown locality in the Vizagapatam district of Madras. He reports also that red and grayish-white crystals, transparent in part, occur in pegmatite veins at Appiyede in the Eraniel taluk of Travancore. The zircon gem stone is found also, in minor quantities, in the ruby mines of Upper Burma, the principal ruby-bearing districts being Mandalay, Mythynia, and the one about Mogok, which includes Kathe. The Burma Ruby Mines (Ltd.), whose chief operations are at Kathe, has workings at Enjouk, Bigom, Nayasen, and other points. The zircons are found in the byon, which corresponds to the illam of Ceylon, and which occupies a position identical with that of the gold gravels in many alluvial regions.

Japan

The following facts with respect to the zircon and other zirconium-bearings ores of Japan are taken from reports by Shibata and Sato.[142 & 143] The matter is presented by ores, as one of them, naegite, is found only in Japan, and oyamalite very closely resembles it.

Zircon and xenotime.--Zircon and xenotime occur in small tetragonal crystals at Ishikawa, Iwaki Province. The color of the former is reddish-brown or brown; the latter is brown or reddish-green. Careful investigation disclosed the fact that these minerals are almost always found associated or intermingled with each other; and that, moreover, sometimes zenotime occurs inclosing zircon in a parallel position.

Analysis of this zircon gave ZrO_2 58.71 per cent and SiO_2 32.40 per cent. The total analysis for zenotime gave ZrO_2 19.34 and SiO_2 12.49 per cent.

Minute and well-crystallized zircon is found in the sand of the Keelung-gawa, Formosa. Large crystals of this mineral occur in a graphite deposit at Jido, Heian-hokudo, Korea. Two specimens of Korean sand, from Jun-an and Sholusan, have been studied. The sand from the latter place was reported to contain 1.05 per cent of zirconium oxide (ZrO_2).

Naegite.--This special Japanese mineral has been found nowhere except at Naegi (Mino Province) up to the present time. It is a brownish-green mineral, having a resinous luster. Its crystal form resembles very much that of zircon; its specific gravity is 4.1; and its hardness is 7.5.

141/ Brown, John Coggin, India's Mineral Wealth: India of To-day, London, 1923, pp. 104-105.

142/ Shibata, Yuji, The Chemical Investigation of Japanese Minerals Containing Rarer Elements: Proc. 3d Pan-Pacific Sci. Cong., Oct. 30 to Nov. 11, 1926, vol. 1, Nat'l. Research Council, Tokyo, 1928, pp. 852-865.

143/ Sato, Denzo, Some Minerals Containing Rarer Elements: Proc. 3d Pan-Pacific Sci. Cong., Oct. 30 to Nov. 11, 1926, vol. 1, Nat'l Research Council, Tokyo, 1923, pp. 865-866.

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Analyses show (1) ZrO_2, 53.03, and SiO_2, 29.55; and (2) ZrO_2, 51.24, and SiO_2, 30.48.

Recently Hevesy reported that naegite contains about 3.5 per cent hafnium.

Naegite has been described as a variety of zircon (radioactive zircon), but it has also been considered to be an isomorphous mixture of ZrO_2, ThO_2, UO_2, and SiO_2.

Hagatalite.--The mineral hagatalite resembles zircon and occurs commonly in small crystals, 1 millimeter to 5 millimeters in diameter, imbedded in biotite. Its color is yellowish-green or green; its specific gravity is 4.4; and its hardness is about 7.5. Analysis gave ZrO_2, 42.0 and SiO_2, 29.7. From the results of analysis it is concluded that this mineral, like naegite, may be a variety of zircon, which contains rare earths and rare acid earths. Hagatalite, however, is clearly distinguishable from naegite by its content of zirconium and also by its general appearance. Hagatalite occurs imbedded in the pegmatite of Hagata-mura.

Oyamalite.--Oyamalite from Oyama, Iyo Province, closely resembles naegite. It occurs imbedded in feldspar, is of a dark green or brown color, has a specific gravity of 4.1 and a hardness of 7.5. Analysis showed 40.9 of ZrO_2 and 25.7 of SiO_2. Evidently oyamalite is a variety of zircon but differs from the latter in that it contains phosphoric acid, whereas zircon seldom does.

Siam

The gem grade of Siamese zircon is discussed in greater detail in a forthcoming information circular upon the semiprecious stone. Eppler refers to blue zircon from Chantaboon, Siam.[144] An American representative in Siam[145] says that, although the quantity of zircon stones produced is not recorded, it is known that they are mined in the region of Chandeburi and the territory along the Mekong River, which forms part of the boundary between Siam and French Indo-China.

The zircons are mined at a depth of 5 to 10 feet below the surface in an alluvial deposit. Single pieces weighing 525 carats have been found.

144/ Eppler, W. Fr., Über das optische Verhalten und Zustandsänderungen des Zirkons: Forts. Mineral., Kristallk. und Petrog. vol. 1, Jena, Germany, 1927, pp. 302-303.

145/ Albrecht, Charles H., American consul, Bangkok, Siam, Zircons: Consular Repts., July 17, 1926, Bureau of Mines foreign file No. 9203.

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AUSTRALASIA

Australia

The gem grade of zircon is reported to occur in New South Wales, Queensland, Tasmania, and South Australia. Government reports of Queensland and New South Wales have included figures of production for the gems, although output has not at any time been very large. Zircon sands also are found in several localities.

New South Wales.--Zircon, the only zirconium mineral known to occur in New South Wales, is a minor accessory mineral in the more acid igneous rocks, such as granite and pegmatites, in river gravels and in beach deposits. It is found in small prismatic crystals, which are a little harder than quartz but not so hard as topaz, and which have a very brilliant luster.146/

Carne says147/ that the auriferous sands of the Esk River and Jerusalem Creek, in the Parish of Esk County, carrying ilmenite, gold, platinum and platinum metals, consist primarily of zircon. They contain some tin also.

A Queensland Government report of 1907148/ reported a proposed development of the sands along the beach of New South Wales, where gold, platinum, tin, monazite, zircon, and other minerals were known to exist. The area to be exploited was 13 miles long by 10 chains wide, paralleling the beach, beginning about 1 mile south of the Evans (or Little) River, approximately 20 miles south of Ballina, at the mouth of the Richmond River, and extending northward to what is known as McAuley's Lead, to within approximately 10 miles of Clarence River. The same publication reported valuable sand deposits about 80 miles north of the beach just mentioned, near Currumbin Creek. Small-scale treatment of the sands had been carried on between Currumbin Creek and Coolangatta.

Western Australia.--Dr. Garcés149/ says that Phipson (Compt. rend. Acad. Sci., vol. 64, pp. 87-88), from a mineralogical study made

146/ Raggatt, H. G., Chromium, Cobalt, Nickel, Zirconium, Titanium, Thorium, Cerium: New South Wales Geol. Survey Bull. 13, Dept. of Mines, Sydney, 1925, p. 14.

147/ Carne, J. E., The Auriferous Sands of the Esk River and Jerusalem Creek in the Parish of Esk County, Richmond, New South Wales: New South Wales Geol. Survey, Vol. 5, 1897, pp. 71-86.

148/ Queensland Government Mining Journal, Beach Mining in New South Wales: Vol. 8, No. 83, Queensland Dept. of Mines, Brisbane, April 15, 1907, p. 175.

149/ Garcés, V. Soriano, Arena Circonífera de Vigo: Trabajos del Museo de Ciencias Naturales de Barcelona, vol. 9, No. 2, Publicaciones de la Junta de Ciencias Naturales de Barcelona, Barcelona, Aug. 13, 1928, p. 9.

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with the microscope of the metalliferous sands of Fremantle, Western Australia, distinguished silicate of zircon, together with quartz, topaz, apatite, and some diamonds.

Simpson says[150] that zircon has been shown to be present in many crystalline rocks in this State, where it can be detected in small, well-formed, colorless or smoky crystals by panning any of the clays (that is, of Bellevue, Belmont, and Mujar) or the river or beach sands, particularly the sands that show through the presence of black iron compounds that they have been concentrated naturally. Simpson lists the following sands where zircon has been found: South Perth, black sand, estuary beach; Cottesloe, white and black sand, sea beach; Koombana Bay, black sand, sea beach; Nannup, with cassiterite in any river sand; Greenbushes, with cassiterite in alluvium of all kinds; Gooseberry Hill, black and white sand, stream; Donnelly River, where zircon forms a large proportion and at times the whole of the concentrates from river sand. At Greenbushes zircon sand could be produced, as a by-product of tin sluicing, in commercial amounts. A sample of sand (30 pounds bulk weight) was analyzed, showing 47.33 of ZrO_2 (Zr, 35.2 per cent). The mineral content, as determined by microscopical examination and analysis, was approximately 71 per cent zircon.

Queensland.--A Government report[151] is to the effect that there was a tendency in Queensland during 1928, on the part of some prospectors, to exploit "nonmetallic minerals," particularly silica, diatomite, zircon, clay, and mica; but that so far no commercial deposits of these minerals had been reported, except in the case of clay. (Twenty-four samples of beach and other sands were tested during the year.)

However, zircon was among the minerals that the Beach Sands Mining Co., at Flat Rock Creek, Tugun, hoped to win through treatment of the sands with a concentrator. A Queensland Government publication[152] reported that this company obtained prospecting rights over a large area of beach sands, extending 4½ miles along the beach at Coolangatta and Currimbin, for the purpose of mining for gold, silver, platinum, and tin, in association with monazite, zircon, tourmaline, topaz, titanium, and other minerals. The company later obtained a mineral lease over 7 acres at Flat Rock Creek, where a treatment station has been erected and where experimental operations have been begun.

150/ Simpson, Edward S., The Rare Metals and Their Distribution in Western Australia; Zirconium: Nat. History and Sci. Soc. of Western Australia Jour., vol. 4, Perth, 1912, pp. 96-93.

151/ Dunstan, B., Chief Government Geologist, Annual Report of the Queensland Geological Survey for the Year 1928: Ann. Rept. of the Under-secretary for Mines, 1928, Brisbane, 1929, p. 127.

152/ Queensland Government Mining Journal, Beach Mining at Tugun: Vol. 29, No. 342, Brisbane, Nov., 1928, p. 469.

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An article[153] concerning the Eungella Goldfield (extending from the head of Broken River, along the slopes of the Clarke Range, which lies 40 miles inland from Mackay) is to the effect that the occurrence of zircon in Broken River wash has long been known and that a definite deposit of zircon wash has been reported. The stones are in grains that average a carat in weight, and most of them are rounded in form. Local miners stated that the stones are found in large numbers in Bull Creek, just above an old reef working and in the main river bed 5 miles above it. Zircons occur in some quantity also on Moonlight Creek (Mount Britten) and at the head of Constant Creek. Evidence is strong that the mineral was derived from the disintegration of the trachyte flows that cap the coast range above each of the places mentioned.

New Zealand

In a bulletin of the New Zealand Geological Survey,[154] pannings from Seven-mile, Greymouth, are said to yield the highest percentage of zirconia in New Zealand. Though zircon is not known to occur anywhere in the island in commercial quantities, the best prospects obtained were in pannings from the Whitcombe River, a little above Cataract Creek, near Price Flat, where the zircon is entangled in moss with fine gold. The gem grade of zircon has not been found; however, crystals from Timbrell's Gully are larger than the ordinary ones.

EUROPE

Austria

Venable reports zircons in the Tyrol (Republic of Austria).[155] Garcés[156] reports that H. Whichman[157] in his work concerning the sands of the Tauern en Gschlöss, Tirol (Tyrol), describes zircon, together with epidote, rutile, tourmaline, and apatite. From the minerals encountered, the author concludes that the sands proceed from gneiss and various species of micaceous slate. The presence of zircon and its forms presupposes granite, chloritic slate, and chloritoids (of which no record exists).

153/ Ball, Lionel C., Eungella Goldfield: Queensland Geol. Survey Pub. 229, Dept. of Mines, Brisbane, 1910, p. 33.
154/ Geological Survey Branch, New Zealand, Minerals and Mineral Substances of New Zealand: Geol. Survey Branch Bull. 32 (New Ser.), New Zealand Dept. Sci. and Ind. Res., Wellington, 1927, pp. 107-108.
155/ Venable, Francis P., Work cited, p. 18.
156/ Garcés, V. Soriano, Work cited, 76 pp.
157/ Whichman, H., _____: Min. Mitth., vol. 7, 1886, p. 452.

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Czechoslovakia

Venable reports zircon in Bohemia,[158] a Province of the Republic of Czechoslovakia. Pratt reports baddeleyite imbedded in phonolite in northern Bohemia.[159]

France

Frossard reports[160] zircon in the granulite at Pic du Midi, vallée de Lesponne, in the neighborhood of Bagnères-de-Bigorre, Department of Hautes-Pyrénées, France.

According to Garcés,[161] the sands of Mesvrin, in Autun, yield zircon, with a number of other minerals, zircon being second in importance. The crystals measure 0.32 by 0.009 millimeter; they are elongated; and they have faces (110), (112), and at times (001), a form very rare in this mineral. The crystals are light-brown, turning green by reflection. Their specific gravity is 4.5. The accompanying minerals are olivine, rose granite, sphene, chromite, tourmaline, and sapphire. The origin of these zircons seems to be the amphibolites of Marmagne.

M. L. Berthois,[162] in an article upon the heavy minerals of the eruptive and schistose crystalline rocks of Brittany, discusses the form of zircon crystals in these rocks in great detail.

Germany

According to Venable,[163] microscopic crystals of zircon are found in the variegated sandstones in the Black Forest (States of Baden and Württemberg), and zircon is found in the sands in the valley of the Main River (States of Bavaria and Hesse).

Bohm reports[164] zircon at Oberlausitz, Province of Saxony, Prussia.

Brauns,[165] in an article upon the effect of radium rays upon

158/ Venable, Francis P., Work cited, p. 18.
159/ Pratt, Joseph Hyde, Work cited, pp. 11-13.
160/ Frossard, M. Ch.-L., Minéraux des environs de Bagneres-de-Bigorre: Soc. Francaise Mineral., Bull. 8, Paris, 1887, pp. 313-314.
161/ Garcés, V. Soriano, Work cited, p. 13.
162/ Berthois, M. L., Minéraux lourds des roches éruptives et cristallophylliennes de Bretagne: Compt. rend., vol. 188, No. 23, Paris, June 3, 1929, pp. 1506-1508.
163/ Venable, Francis P., Work cited, p. 18.
164/ Bohm, C. Richard, Work cited, pp. 108 and 116.
165/ Brauns, R., Der Einfluss von Radiumstrahlen auf die Farbung von Sanidin, Zirkon and Quarz; Kristallform des Zirkons aus Sanidinit vom Laacher See: Centralb. Mineral., Geol. and Palaon., No. 23, Stuttgart, Dec. 1, 1909, pp. 722-726.

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the color of zircon (as well as of sanidine and quartz), refers to zircon from Laacher See, from Niedermendig, and from Pfitsch.

Of the zircon from Laacher See, the author says that in the sanidinite microscopic zircon occurs in two ways for the most part, in some places growing up in geodes (or vugs) and in some places being embedded in sanidinite. It is less frequently found embedded in sanidinite. The first-mentioned form builds small, thin, dominant, prismatically formed crystals. As a rule, the thickness of the prism is less than a millimeter, and the length is from 2 to 4 millimeters.

Specimens from the basaltic lava of Niedermendig the author describes as an embedded, red, long, prismatic zircon crystal, the measurements of which are not reported, as the surfaces are rounded. The only description of the specimens from Pfitsch is that they are colorless crystals, which did not acquire a trace of color when subjected to the radium rays.

Great Britain

A detailed description of the purple zircon in British sedimentary rocks is given by Boswell,[165] from whose work the following excerpts are taken.

The purple or rose-colored variety of zircon is especially characteristic of those British sediments in which minerals derived from regionally metamorphosed rocks are abundant and of fresh appearance. They provide additional evidence that the deposits were formed by denudation of island masses composed of crystalline metamorphic rocks.

British deposits in which purple zircon may be considered an abundant and characteristic constituent of the sediments and in which it is accompanied by other significant detrital minerals are the various divisions of the Carboniferous, Permian, and Bunter rocks, and the Lower Greensand.

In the Carboniferous rocks of Scotland and northern Ireland, purple zircons are found in great abundance, and they are often of a typical deep color and of ovoid form.

In the Permian rocks, to the north of England, purple zircons are by no means uncommon.

The purple zircon is a characteristic and common constituent of Triassic sediments; it appears to be abundant in the Bunter rocks; and it is found throughout Yorkshire, Derbyshire, and Nottinghamshire, the

165/ Boswell, P. G. H., On the Distribution of Purple Zircon in British Sedimentary Rocks: Mineral Mag. and Jour., vol. 21, Mineral. Soc., London, 1928, pp. 310-317.

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Midlands, the Welsh borders, Lancashire, Cheshire, the Vale of Clwyd, Cumberland, Antrim, and Arran.

The localities where purple zircon is plentiful in the Lower Greensand are almost too numerous to mention, but they range throughout the outcrop north and south of the Weald, the Isle of Wight, Berkshire, Oxfordshire, Bedfordshire, Buckinghamshire, Cambridgeshire, and Norfolk.

Greenland

Venable reports zircon in Greenland.[167] According to a report of the U. S. Geological Survey,[168] eudialite is found at one locality in southern Greenland.

Gordon, in his description of the noted cryolite mine at Ivigtut, Greenland, states that eudyalite is of common occurrence in the alkaline syenites about the Tunugdliarfik and Kangerdluarsuk fiords of the Julianehaab district; and that 55 tons were collected for technical purposes, according to K. J. V. Steenstrup. It occurs disseminated in the rock, as well as in veins, and Gordon remarks, perhaps prophetically, that "this district should become an important producer of this mineral if a use for it is ever discovered. . . ."[169]

Holland

In the sand dunes of Holland a small percentage of zircon has been found, the zircon and rutile together comprising 0.05 per cent of the mineral constituents of the sand. The zircon has a specific gravity of 4.8 to 4.5.[170]

Hungary

An examination of the sands taken from the bed of the Danube River at Budapest revealed that the sands contain opal, granite, magnetite, quartz, calcite, apatite, tourmaline, zircon, rutile, etc. The zircon is among the minerals mentioned as having their origin in the Alps. Zircon occurs in rounded grains and in less rounded forms, colorless prismatic crystals, measuring 0.18 to 0.25 millimeters.[171]

167/ Venable, Francis P., Work cited, p. 13.
168/ Pratt, Joseph Hyde, Work cited, pp. 11-13.
169/ Lee, O. Ivan, Work cited, pp. 29-35.
170/ Garcés, V. Soriano, Work cited, p. 17.
171/ Zeitschrift für Krystallographie und Mineralogie, Abstracts, Daten zur mineralogischen Kenntnis des Sandes der Donau: Vol. 53, Leipzig and Berlin, 1914, pp. 61 and 64.

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Italy

Baddeleyite is found in Italy, according to Schaller.[172]

Dr. Garcés[173] says that Artini, in his work[174] on the mineralogy of the sands of Tesino, at the extreme southern part of Lake Como, reports the separation of zircon, with gold, pyrite, ilmenite, magnetite, rutile, and other minerals.

Garcés[175] reports also that Uzielli[176] studied various specimens of sand from Porto d'Anzio and from the coast between Naples and Civitavecchia, where he found zircon, always accompanied by augite, olivine, monoclinic feldspar, titaniferous magnetite, and calcite. In the sands occurred also quartz, plagioclase, leucite, and apatite. Judging from the distribution of zircon from the mouth of the Volturno River toward the north along the entire coast, from the state of preservation of the crystals, from their prismatic form, from their yellow color, and from the difference of this zircon from that of Vesuvius (which is octohedral and blue), Uzielli inferred that the deposits were chiefly alluvial, except toward the south, where they were probably ocean deposits.

Of the altered zircons, cyrtolite is known in Italy.[177]

Norway

Venable reports zircon in Norway.[178] According to Iddings,[179] zircon occurs very abundantly in certain syenites of Norway. Pratt[180] locates the following noncommercial zirconium-bearing minerals, in southern Norway: rosenbuschite, associated with zircon, elaeolite (eleolite), etc., in syenite; lovenite, associated with elaeolite syenite; eudyalite in syenite; catapleiite, hiortdahlite, polymignite, and several other minor zirconium minerals, associated with zircon in syenite. Wöhlerite occurs in zircon syenite on several islands along the southern coast of Norway.

172/ Schaller, Waldemar F., Zirconium and Rare-Earth Minerals: Min. Res. of the United States, 1916, pt. 2, U. S. Geol. Survey, 1917, pp. 377-386.
173/ Garcés, V. Soriano, Work cited, p. 16.
174/ Artini, E., _____: Giorn. min. i petr., vol. 2, 1891, pp. 1-19. (Neues Jahrb., vol. 1, 1892, p. 515.)
175/ Garcés, V. Soriano, Work cited, pp. 10-11.
176/ Uzielli, G., _____: Atti R. Accad. Lincei, vol. 3, 1876. (Neues Jahrb., 1877, p. 303.)
177/ Lee, O. Ivan, Work cited, pp. 29-35.
178/ Venable, Francis P., Work cited, p. 18.
179/ Iddings, Joseph Paxson, Rock Minerals, Their Chemical and Physical Characters and Their Determination in Thin Sections: New York, 1906, 548 pp.
180/ Pratt, Joseph Hyde, Work cited, pp. 11-13.

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Bohm[181] reports eudyalite at Brevik (Brevig) and Skudesundskjar, near Barkevik, Norway.

Portugal

A zircon crystal (red hyacinth) was reported at Mount Suimo (Bellas, near Lisbon).[182]

Roumania

Venable reports zircon in Transylvania,[183] a division of the new kingdom of Roumania.

Russia

Since 1920 the Mineralogical Museum of the Academy of Sciences of the Union of the Socialist Soviet Republics and the Research Institute of the North together have been investigating alkaline rocks in the central part of the Kola Peninsula, lying between 67°35' and 67° 55' north latitude, in districts known as Hibina- (or Umptek) and Lujavr-Toundra (or Lujavr-urt). The total area of the massives is 1,600 square kilometers. The country is barren, badly dissected, 1,200 meters above the level of the sea, covered with swamps and forests, and free from snow only two or three months of the year, during the polar summer. However, this region has first rank among mineral districts for the beauty of the specimens, for the pecularity of the minerals, the number of rare combinations, and for the interesting genetic relationships. Fersman[184] says that 15 of the 90 minerals found in the nepheline syenites and their endocontact zones are zircono-titano-silicates (of the eudyalite group): aenigmatite, astrophyllite, eucolite, eudyalite, lavenite, lamprophyllite, lovchorrite, mangan-neptunite, mesodialyte, murmanite, ramsayite, rinkolite, rosenbuschite, titano-elpidite, and wöhlerite.

Kostilewa[185] has given a full description of the work in the Kola Peninsula with respect to zirconium-bearing ores and also of the zircon region of the Urals, a translation of which follows, as well as a translation of his discussion of the economic status of zircon in Russia.

181/ Bohm, C. Richard, Work cited, pp. 108 and 116.
182/ Bello, A., Portugiesische Mineralien; Zircon: Ztschr. Krystall. und Mineral., vol. 53, No. 1, Leipzig and Berlin, 1913, p. 56.
183/ Venable, Francis P., Work cited, p. 18.
184/ Fersman, A. E., Minerals of the Kola Peninsula: Am. Mineral., vol. 11, Mineral. Soc. Am., Nov., 1926, pp. 289-299.
185/ Kostilewa, von E., Zirkonium: Ztschr. prakt. Geol., Mar. 27, 1929, pp. 42-45.

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Kola Peninsula

Deposits of eudyalite and eucolite occur in the Chibina Tundra (Umptek) and in the Lujavrut of the Kola Peninsula, where these minerals accompany veinlike segregations in the nepheline syenite. The width of these vein segregations is never great. On an average, their width is ½ meter, and their length is 3 to 5 meters. Their form is generally lenticular. The vein segregations lie along the slopes and upon the plateau-like mountain crest, 300 to 1,000 meters high. The amount of eudyalite in some of these veins reaches 30 to 40 per cent of the weight.

The minerals that most generally accompany the eudyalite are aenigmatite, aegirine, , lamprophyres, rinkite ("rinkolite"?), nepheline, feldspar, less often titanium, etc.

Considering the narrow width of the pegmatite veins that contain eudyalite, only a small number of the districts that are rich in such veins can have practical significance.

To such districts belong, as a result of the expedition of A. Fersman (member of the Academy) into the Umptek in 1920, the following:

1. Eudyalite-aenigmatite segregations of the plateau of the South Tschasnatschorrs, which are situated in the valley of the Lutnermajok River, at a distance of 4 to 5 hours from the station of Chibina.--The deposits are on the plateau-like crest of the massif at a height of 1,000 meters above the Imandra Lake (the ascension requires 1½ to 2 hours). They are composed of alluvial beds of primary deposits and of lenticular segregations at Chibinit. A small amount of ore can be collected by hand; a greater yield will require a different method of mining.

2. The northern Zirkus of the Tschasnatschorr, which opens into the Tschasnaiokal, 7 hours from the station of Imandra.--This deposit presents detached accumulations of large bowlders of nepheline syenite strongly enriched with eudyalite at the bottom or base of the Talzirkus (200 to 300 meters high).

In order to calculate the reserves of eudyalite in this district, special research will be necessary; nevertheless temporary observations during the course of the expedition have already indicated that this deposit is richer than that of the southern Tschasnatschorr. For the purposes of production, the great fault blocks will have to be blasted or broken up in some other way.

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3. The district of the northern Ljavotschorr, the southern slope of the Ljavajoktals.--This district lies at a distance of 8 to 9 hours, over bad roads, from the station of Imandra. The district is the richest in eudyalite. It is composed of numerous lenticular segregations of eudyalite, lamprophyres, aegimatite, and rinkite (rinkolite?), stretching from northwest to southeast, one of which was opened up by blasting, by the expedition of the Academy of Science and of the Institute of the North. This deposit afforded approximately 160 kilograms of eudyalite, with rinkolite and lamprophyres (a rich material for scientific and museum purposes). These segregations, however, can not yet be worked and assembled; they lie as rich material upon the place of their occurrence. The presence of rinkolite (which is rich in cerium oxide and which can be won together with the eudyalite) increases the value of this deposit.

The eudyalite found in this vein has the following analysis:

	Per cent
SiO_2	49.43
ZrO_2	15.30
TiO_2	1.59
Fe_2O_3	--
Al_2O_3	--
$(Th)_2O_3$	0.52
FeO	5.01
MnO	0.30
CaO	12.29
MgO	--
Na_2O	15.30
K_2O	--
H_2O	1.05
Cl	1.06
Total	100.08

In order to calculate the total amount of eudyalite in this region, a special investigation will be necessary; however, one can now take for granted that here at least 2 tons of eudyalite are at hand. For production, blasting will be necessary.

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4. The Privince of Zirkus Sengis in Lujavrut.--Upon the northwest slope of the Sengistschorr, about 400 meters high, are found outcrops of eudyalite-lujavrit, which contains 20 to 40 per cent of eudyalite. The outcroppings of this rock, several meters in width, can be traced many thousand meters along the whole slope of Talzirkus; and they indicate significant accumulations. The eudyalite in this rock has the form of little, pillar-shaped crystals, which are regularly scattered in the mass of feldspar, of nepheline, and of the other minerals of the rock. No special research into the character of these stratifications and no estimate of the quantity of the eudyalite have been attempted. At the present time, it is impossible to reach these deposits, since all connection with the railroad, which is more than 80 kilometers distant, is lacking.

Doubtless new deposits will be found through further searching in Umptek and Lujavrut, which for the practical exploitation of eudyalite will be of importance.

Urals

The most important district for the production of zircon in the Urals is that of the Ilmen Mountains, where the outcropping of zircon is associated with pegmatite veins.

The Ilmen range of mountains is, in a petrographical sense, built up of granite gneiss, nepheline-syenite (miascite), and syenite. The lateral extensions of the granite gneiss are the most significant. The zircon-bearing pegmatite veins lie chiefly in syenite, less often in granite gneiss, and still less often in miascite. The chief distributional area of zircon-bearing veins is the southern part of the main massifs of the Ilmen Mountains, between Lake Miass in the north and Lake Ilmen in the south. It consists of miascite and is inclosed by small outcroppings of syenite rock. Numerous mining works, which have been in existence since 1828, are developing pegmatite veins of almost the same structure. The rock of the veins consists in all the mines almost entirely of white and red potash feldspar, with biotite and a little eleolite. The zircon is in large and small crystals, 2 to 3 centimeters in diameter, inclosed especially in feldspar, less frequently in biotite, and still less frequently in eleolite.

Accessory minerals, which accompany the zircon in the veins, are magnetite, pyrochlore, apatite, etc.

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The principal mines that are worthy of note are in the following districts:

On the left bank of the Tscheremschanka River.--A group of deposits, established by Barbot de Marny and F. Blum, lies on the left bank of the Tscheremschanka River. The zircons occur in rather large quantities; they are transparent, brownish-red, but not very large. The largest mine reaches the length of 24 meters by a depth and width of 6 meters. In the year 1837 the largest zircon crystal that was ever found in the Ilmen Mountains was won here. It weighed 3.5 kilograms.

Vicinity of Roschkow Springs.--The mines in the vicinity of Raschkow are the mines of Redikortzew. On the left bank in granite gneiss are two mines, the larger of which is 4 meters long and about 2 meters wide and deep. The zircons found here are pure but not large.

Mines along the Kamenka and Uzkow Springs.--The deepest mine, established in the presence of the acadamician N. Kokscharow, is about 50 meters long, 3 meters deep, and about 1½ meters wide. This mine has yielded numerous and very large crystals, 7 to 8 centimeters long.

The zircon mines of Gasberg.--The largest of these mines, about 8 meters long and approximately 1½ meters deep and wide, has yielded numerous, though not very large, crystals.

The Blumsche mine.--The Blumsche mine, one of the richest, is found in Absturz, on the left bank of Uzkow Springs. It has for some time yielded a quantity of crystals. In the summer of 1926, through the South-Ural-Trust, 480 kilograms of zircon were washed from the deposits of this mine.

It is impossible to calculate the reserves of zircon in the mines described above; for the pegmatite veins have seldom come to the surface, and the whole district is poorly explored. Doubtless in the near future new zircon-bearing veins will be uncovered. The exploitation of zircon by blasting will be certainly very costly and not sufficiently productive, as the occurrence of zircon in the mines is very scattered and seems to be by chance. Of greater importance are the natural outcrops of pegmatite and the dumps of old mines that accumulated during the working of the mines in the Ilmen Mountains. Only through the washing of these deposits can the extraction of zircon be productive and profitable--a fact that the output of the summer of 1926 has already shown. One may conjecture that through the washing of these deposits in the Ilmen Mountains not less than 1,600 kilograms of zircon can be won.

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Besides the deposits in the Ilmen Mountains, in the recent period of the activity of the "Rare Elements" trust, new deposits of zircon sands in the Province of Transbaikalia (in Siberia) have been found. They are in the vicinity of the wolframite occurrences, and their sands contain about 2 per cent of zircon.

Output

The production of zircon in the Ilmen Mountains has already (since 1828 to the present time) been undertaken by Barbot de Marny, Kokscharow, and Blum, exclusively as museum material. First in the eighties, when the foreign market showed interest in zirconium, and when inquiries from abroad concerning zirconium were received, the winning of zircon in the Illmen Mountains, through the washing of mine deads, began. The peak of the industry was in 1887. In the summer of that year 410 to 640 kilograms of zircon arrived at the Petersburg mineral market for further sale abroad. At the same time, however, the foreign inquiries ceased, and the Russian zircon was taken out of trade (commerce), since cheap American zircon had conquered the world market. An enormous slump in prices was the result. From that year on the production of zircons in the Urals ceased or was carried on only by collectors for museum purposes.

In time, interest in the production of zircon revived. From 1925 on, the South-Ural-Trust carried on at the same time its searching for and the production of zircon.

The production of eudyalite has not again been started, unless one takes into consideration the research expedition, under the name of the Mineralogical Museum of the Academy of Science, in the summer of 1925. It was organized in the plateau district of the Southern Tschasnatschorr. It obtained about 20 kilograms of ore, which was rich in eudyalite.

Spain

The zirconiferous sand of Vigo,[186] a port on the northwestern coast of Spain, is of gem grade ("gemmiferous"), like that of Ceylon, and is extraordinarily rich in zircon. The proportions of the different minerals in the sands are shown in the following table.

186/ Garcès, V. Soriano, Work cited, 76 pp.

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	Per cent
Zircon	67.3
Rutile	7.6
Magnetite	7.1
Quartz	6.7
Feldspar	3.2
Estaurolite	2.9
Cassiterite	1.2
Voigtite ("vigoita")..	1.0
Tourmaline	.3
Limonite	.2
Almandine (garnet) ...	.2
Others	2.2
	99.9

This proportion of 67.3 per cent of zircon is unusually high. Dr. Garcès classifies the crystals observed at Vigo under four different types. The most abundant of these types is a crystal described as a combination of faces that measure (100), narrow, (110), and (111), with slight altitude. The general color of these crystals is that of honey, slightly reddish in tinge, but some crystals are whitish. The two colors give to the sand its characteristic light-brown cast. The Vigo zircons, probably present originally in granites and granite porphyry, are as a rule little worn; they were accumulated in a zone where surge and tide are slight.

Dr. R. de Buen[187] determined the presence of zircon, with quartz, orthoclase, plagioclase, and numerous other minerals, in the bay of Palma de Mallorca, most of the rare and heavy minerals being in the interior part of the bay, where it felt the influence of the port-side river detritus.

Zircon is reported to be in the rich mercury ore of Almaden, Spain, the description by Beck being as follows: "Cinnabar between grains of quartzite and formed by replacement in quartz, also showing sericite, pyrite, and zircon."[188]

Sweden

Zircon on the Island of Alnö, on the southeastern coast of Sweden, when analyzed by P. J. Holmquist, showed the following proportion of mineral oxides:[189]

187/ Buen, R. de, Estudio batilitológico de la bahía de Palma de Mallorca, Trabajos de Oceanografía y Biología marina, dirigidos por el Prof. Dr. Odón de Buen, Director del Institute Español de Oceanografía, Madrid, 1916.

188/ Lindgren, Waldemar, Work cited, p. 495.

189/ Högbom, A. G. (In Upsala, earlier in Stockholm), Mineralien von Alnö; Über das Nephelins-yenitgebiet auf der Insel Alnö: Geol. Fören. Förh., vol. 17, 1895, p. 100.

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	Per cent
Zirconium oxide ...	64.94
Silicon oxide	29.68
Titanium oxide	Trace
Manganese oxide ...	.28
Iron oxide	1.15
Hydrogen oxide	3.86
	99.91

Baddeleyite[190] also has been identified in Sweden, as well as cyrtolite.[191]

Switzerland

O. Meyer, in 1878, described microscopic twin crystals growing out of the hornblende and the mica and limestone slate of the St. Gothard tunnel. E. Hussak found in the same rocks polysynthetic twinning, which, according to a later notice, Meyer also observed.[192]

190/ Schaller, Waldemar F., Work cited, pp. 377-386.
191/ Lee, O. Ivan, Work cited, pp. 29-35.
192/ Jahresbericht über die Fortschritte der Chemie für 1878, Mineralogie; Oxyde, Hydroxyde, Oxydhydrate; Zirkon, Rutile, Brookite: Vol. 31, Giessen (Hesse), 1880, p. 1214.

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